(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 468 110 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **90308105.7**

(51) Int. Cl.[5]: **B08B 7/00**, H05H 1/48

(22) Date of filing: **24.07.90**

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(43) Date of publication of application:
29.01.92 Bulletin 92/05

(84) Designated Contracting States:
BE CH DE FR GB IT LI

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(54) Electric arc treatment of parts.

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(57) A part being treated, e.g. cleaned, and one or more electrodes are connected to a power supply and an arc discharge is initiated at a pressure below 10 Pa between the part and the electrode(s) in the mode of a drooping portion of the voltage-ampere characteristic of the arc or using a power supply charging a drooping external volt-ampere characteristic. In one precedure, during arcing, a difference of potentials of electric field approximately equal to zero is created on the treatment zone of the part and/or on the working surface of the electrode(s) and the area of movement of the arc plasma is limited to the said zone and/or the said working surface. In another procedure, a difference of potentials other than zero is created, areas with the highest and/or lowest potential being moved along the treatment zone and/or working surface, and the area of movement of the arc plasma being limited to the treatment zone and/or working surface. In another procedure the region of the arc discharge in the space between the part and the electrode(s) is positively compressed or partly restricted, and the said region and the part are moved relative to each other according to a predetermined program.

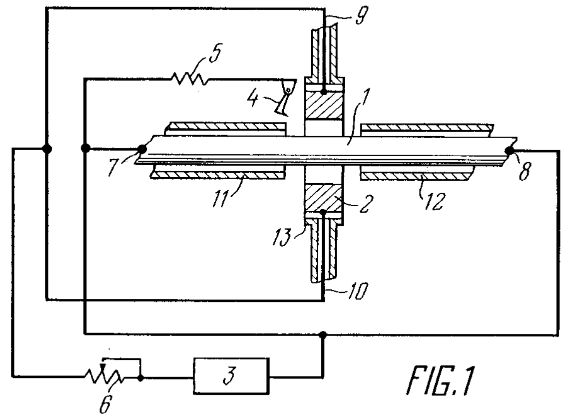


FIG.1

The invention relates to the electric arc treatment of parts, and more specifically, it deals with method and apparatuses for electric arc treatment of parts.

There is now a problem of high-grade treatment of parts before deposition of coatings. Existing processes for preparation of parts before deposition of coatings bascially involved chemical and mechanical treatment which are labour-consuming and low-productive. In addition such methods cause pollution of the environment.

Other treatment methods have recently emerged.

Known in the art is a method for treating parts (SU-A-322420) wherein a part to be treated is placed between two electrodes in a vacuum chamber, and a glowing discharge is initiated between the electrodes. The product is subjected to ion bombardment in the glowing discharge so that its surface is cleaned and activated.

The process is characterised by uniform cleaning of the part surface, but its productivity is rather inadequate because of a low rate of atomization of materials in the glowing discharge. In addition, this technique is not capable of ensuring removal of fine burs.

Known in the art is a method for electric arc cleaning of the surface of metal parts and an apparatus for carrying out this method (SU, A, 935141, B 08 B), wherein the surface of a metal part placed into a chamber is acted upon by an arc discharge under a gas pressure of 10^2 to 10^4 Pa. The surface being cleaned is exposed to the arc discharge in a pulsed mode, with a pulse rate of 10 to 100 Hz and with an energy of individual pulses of 0.5 to 60 J.

The use of a pulsed arc discharge for cleaning allows temperature on the surface of the part being cleaned to be controlled by varying pulse rate and energy of individual pulses so as to intensify the cleaning process.

This method of electric arc cleaning cannot bring about uniform treatment of a part over the entire surface area because of difficulties in controlling position of spots of the pulsed discharge within a predetermined area of the surface. This results in noncleaned portions and nonuniform heating of the part. Sophisticated devices should be used to carry out this method.

Known in the art is a method for electric arc treatment, preferably, for cleaning parts, e.g., inner surface of pipes (SU, A, 952388, B08B), comprising connecting a part and an electrode to a power supply and initiating an arc discharge between the part being treated and the electrode under a pressure of a medium of 100 to 500 Pa. The electrode is then caused to move with respect to the part so as to move plasma of the arc discharge along the surface of the part being treated which functions as a cathode.

This method is carried out by means of an apparatus having an electrode mounted on a holder and connected, by means of a current supply member, to one lead of the power supply having a second lead which is connected to the pipe being treated, an arc excitation system, a mechanism for reciprocating the electrode, and a system for sealing and evacuating the interior space of the pipe being treated.

However, with these method and apparatus in use, a medium pressure in the treatment zone should be at least 100 Pa, and the residual gas reacts with the surface of the part being treated heated by the arc discharge. This results in the treated portions of the surface, which are already cleaned, being oxidized.

From the physical point of view, mobile electrode spots are not formed under such pressure, and a volumetric discharge develops so that a major part of power released in the discharge is spent for heating of the part and electrode. As a result, only a minor part of power released in the arc is used for producing useful result, i.e., cleaning of the part surface. The formation of a volumetric discharge results in plasma acting upon parts of the apparatus which are in contact with the plasma, in particular, upon the electrode holder and the system for sealing the interior of the pipe so that their service life is shortened.

Since density of energy released on the part under such pressure is low, only thin (several μm) oxide films can be removed from the part surface, and thicker (deeper) oxide layers and scale cannot be removed by using this method.

For carrying out the prior art method, it is necessary, in any case, to have a sophisticated apparatus having movable electrodes which is not justified in many applications, especially if simple parts of finite dimensions are to be treated.

We have discussed disadvantages of known methods and apparatus designed, preferably for electric arc cleaning of parts. Known techniques in such fields of electric arc vacuum treatment as heating, welding, cutting, etc. also have similar disadvantages, and their discussion is not given here.

Disclosure of the Invention

The invention is based on the problem of providing a method for electric arc treatment of parts in which, owing to the choice of process steps ensuring a predetermined distribution of plasma over the surface of parts, the desired quality of treatment of parts, high productivity, and ecological safety of the process can be achieved. Another

problem is to provide an apparatus for carrying out this method and also to provide an optimum construction of components of the apparatus so as to achieve advantages of the invention in the best possible manner.

The above problem is solved by the fact that in a method for electric arc treatment of parts, comprising connecting a part being treated and at least one electrode to a power supply and initiating an arc discharge between the part being treated and the electrode under a pressure of a medium below atmospheric pressure, with the formation of plasma moving at least along the cathode, according to the invention, the process is carried out under a pressure of a medium below 10 Pa, the arc discharge is initiated in the mode of a drooping portion of the volt-ampere characteristic of the arc, and/or a power supply with a drooping external volt-ampere characteristic is used, during arcing, a difference of potentials of electric field equal, or close to zero is created at least on the surface of the treatment zone of the part and/or on the working surface of the electrode, and limiting the area of movement of the arc plasma is limited to the treatment zone of the part and/or to said electrode surface.

If a medium pressure is below 10 Pa, the electrode spots of the arc can spontaneously move over the surface of the part and electrode and, if an arc is initiated in the mode of a drooping portion of the volt-ampere characteristic or, which is the same, if a power supply with a drooping external volt-ampere characteristic is used, mobility of the electrode spots substantially increases as shown by tests. If a difference of potentials of electric field equal, or close to zero is created on the surface of the treatment zone of the part and/or on the working surface of the electrode, the electrode spots of the arc will most likely occur in all areas of respective surfaces. Therefore, if the area of movement of the electrode spots is limited to said surfaces, a sufficiently uniform treatment, in particular, cleaning of parts with the arc can be achieved with minimum erosion of the electrode. It should be noted that, owing to low pressure of a medium, oxidation of the treated surface of the part is eliminated. If a part of finite dimensions is treated, no movement of the part is required during the entire treatment process.

In addition, the problem is also solved by the fact in a method for electric arc treatment of parts, comprising connecting a part being treated and at least one electrode to a power supply, initiating an arc discharge between the part being treated and at least one electrode under a pressure of a medium below atmospheric pressure, with the formation of plasma at least on the cathode, according to the invention, the process is carried out under a pressure of a medium below 10 Pa, the arc discharge is initiated in the mode of a drooping portion of the volt-ampere characteristic, and/or a power supply with a drooping external volt-ampere characteristic is used, a difference of potentials of electric field other than zero is created on the surface of the part and/or on the surface of at least one electrode, portions with the lowest potential are moved in accordance with a preset program along the surface of the part being treated and/or along the electrode surface, and the area of plasma movement is limited to said surfaces of the part and/or electrode.

In this embodiment of the method, the electrode spots of the arc move to follow up said areas of extremum values of potential so as to ensure treatment of the part in accordance with a preset program.

It is preferred that the difference of potentials of electric field be created by supplying electric current to areas of the part and/or electrode remote from the zone of location of the electrode spots of the arc, the areas of the highest and/or lowest potential of electric field being moved by varying position of current supply zones on the part and/or on the electrode.

This method does not call for additional energy expenditures for moving the electrode spots with respect to a part.

In treating elongated parts, e.g., rolled stock, it is preferred that the part be moved with respect to at least one electrode, or at least one electrode be moved with respect to the part.

This movement allows the whole surface of such parts to be uniformly treated.

The above problem is also solved by the fact that in a method for electric arc treatment of parts, comprising connecting a being treated part and at least one electrode to a power supply and initiating an arc discharge between the part being treated and at least one electrode under a pressure of a medium below atmospheric pressure, with the formation of plasma moving at least along the cathode, according to the invention, the process is carried out under a pressure of a medium below 10 Pa, the arc discharge is initiated in the mode of a drooping portion of the volta-ampere characteristic of the arc, and/or a power supply with a drooping external volt-ampere characteristic is used, the area of the arc discharge being positively compressed in, or partly limited to the space between the part being treated and at least one electrode, this area of the arc discharge being moved in accordance with a preset program with respect to the part, and/or the part being moved with respect to this area of the arc discharge.

In this embodiment of the method, the electrode spots of the arc move along the part surface to follow up said area of the arc discharge so as to

achieve the desired treatment of the part.

It is preferred that electric current be supplied to the part in the area to which the discharge is limited, on the side opposite to the arc excitation zone.

The electrode spots of the arc are thus shifted along the part towards the current supply zone but, since their movement is limited, they are concentrated at the boundary of the area to which the arc discharge is limited and, during the relative movement of the part being treated and this area to which the arc discharge is limited, the desired treatment of the desired surface of the part with these spots is achived.

It is preferred that, in case there are at least two electrodes, the value of electric current be limited, or electric current be interrupted in accordance with a preset program in the circuit of at least one electrode, the current in the circuit of other electrodes remaining unchanged or being increased.

A change in direction of electric field which will thus occur in the discharge gap is capable of ensuring a respective directinal movement of the electrode spots along the part without using movable electrodes so as to ensure treatment of the part in accordance with a preset program.

The part being treated may be connected to either negative or positive terminal of the power supply. The former case is most preferable for cleaning, descaling, deburring, and vaporization of the material of a part, and the latter case is most suitable for polishing, heating, welding, and cutting of parts.

It is preferred that, during the electric arc cleaning, the value of arc current and treatment time be such that the specific energy consumption be within the range from 0.1 to 0.8 kW-h/m^2 μm.

These conditions can ensure complete removal of scale from the surface being cleaned without an appreciable erosion of the part being treated and with a high enough productivity of the process.

The above problem is also solved by the fact that an apparatus for carrying out the method for electric arc treatment of parts, comprising at least one electrode mounted on a holder and connected by means of a current supply member to one lead of a power supply having the other lead connected to a part being treated, and an arc excitation system, according to the invention, is provided with at least one means electrically connected to the power supply for creating, during arcing, a difference of potentials of electric field equal, or close to zero, on the surface of the treatment zone of the part and/or on the working surface of at least one electrode and with a means for limiting movement of plasma of the arc discharge to the treatment zone of the part and/or to the working surface of at least one electrode.

The provision of said means for creating a difference of potential of electric field equal, or close to zero and the means for limiting movement of plasma of the arc in the apparatus according to the invention ensures substantially identical probability of occurrence of the electrode spots in all areas of the treatment zone of the part and/or the working surface of the electrode and rules out movement of such spots to other areas of the surface of the part and/or electrode, whereby a sufficiently uniform treatment of the selected zone of the part with the arc is ensured with minimum erosion of the electrode.

The means for creating, during arcing, a difference of potentials of electric field equal, or close to zero on at least the working surface of the treatment zone of the part may be in the form of at least two current supply members connected to the part symmetrically with respect to the treatment zone, electrically connected to each other and to one of the leads of the power supply, and a similar means for creating, during arcing, a difference of potentials equal, or close to zero on the working surface of at least one electrode may be in the form of at least two current supply members connected to the electrode symmetrically with respect to the treatment zone of the part or to the working surface of the electrode, electrically connected to each other and connected to the lead of the power supply opposite to that to which current supply members of the part are connected.

This construction of the above-mentioned means can be most easily implemented in practice owing to a simple design.

If the apparatus has at least two electrodes, it is preferred that they are positioned symmetrically with respect to the treatment zone.

This facility prevents asymmetry of erosion of the part being treated.

It is preferred that, if the apparatus has at least two electrodes, the electrodes be mounted for movement relative to each other.

This facility allows the width of the treatment zone to be controlled.

In carrying out the electric arc treatment, preferably, cleaning of parts in the form of bodies of revolution, it is preferred that the electrodes be in the form of coaxially mounted truncated cones having coaxial holes to receive a part being treated therein, their smaller bases facing towards each other, the angle between the generant and height ranging from 35 to 85°.

Owing to this construction of the electrodes, products of erosion of the part being cleaned are practically completely removed from the area of the discharge gap, and only a minor fraction of these products will be deposited on the working

surface of the electrodes so as to ensure high reliability and prolonged service life of the apparatus. The angle between the generant and height of the cones ranging from 35 to 85° is determined experimentally; with angles smaller than 35° stability of arcing is compromised, and with angles greater than 85°, the major part of erosion products will be deposted on the electrodes so as to result in a rapid failure of the apparatus.

The current supply members should be connected to the electrodes at the larger bases of the truncated cones; in addition, the current supply members should be connected to one of the electrodes with an offset towards the other electrode at one-half of the distance between the current supply members.

This connection of the current supply members allows a zig-zag movement of the cathode arc spots along the perimeter of the part being treated so as to enhance uniformity of treatment and lower the probability of fusion of the part during its cleaning.

In carrying out the electric arc treatment, preferably, of rolled stock, it is preferred that the electrodes be made in the form of at least one pair of mirror-parallel prisms, with an angle between facets facing towards each other ranging from 35 to 85°. Similarly to the above-described embodiment of the electrodes in the form of truncated cones, this construction allows the major fraction of erosion products from the part being cleaned to be removed from the discharge gap area so as to enhance reliability and prolong service life of the apparatus. The range of 35 to 85° for this angle is chosen as described above.

In carrying out treatment, preferably cleaning of strip rolled stock, it is preferred that the electrodes in the form of at least one pair of mirror-parallel prisms be mounted symmetrically with respect to the axis of the rolled stock and in parallel wherewith, and if at least two pairs of mirror-parallel prisms are provided, they are preferably positioned along the path of movement of the strip stock.

This facility allows a large surface area of the strip stock to be cleaned uniformly thereby enhancing productivity of the process.

In certain applications, it is preferred that the electrodes be mounted with respect to each other so that the threatment zone of each of the arc discharges be covered by the treatment zone of at least one other arc discharge.

This facility allows a part to be uniformly treated with a plurality of arcs at a time so as to acieve a respective increase in productivity of the process.

It should be noted that, in carrying out treatment of strip rolled stock, the apparatus is preferably provided with at least two pairs of identical electrodes mounted on holders, the electrodes being preferably mounted pairwise symmetrically with respect to a plane drawn at right angles with respect to the direction of movement of the rolled stock substantially through the middle of the treatment zone of the rolled stock.

This construction of the apparatus allows cleaning of strip rolled stock to be carried out with any section of the stock at a desired speed owing to the parallel and consecutive average of the surface being treated during movement of the rolled stock by arc discharges.

It is preferred that the apparatus be provided with additional electrodes mounted symmetrically with respect to the main electrodes on the opposite side of the rolled stock.

This facility allows the two-sided treatment of the strip stock to be carried out simultaneously.

It is also preferred that, in case the apparatus has at least two electrodes, the apparatus be provided with a switch for switching the current supply members of these electrodes which is capable of ensuring premanent contact of at least one electrode with the power supply.

This switch is used for reversing the direction of electric field in the discharge gap without interruption of the arc so as to achieve the directional movement of the electrode spots of the arc along the part without moving the electrodes.

The above problem is also solved by the fact that an apparatus for carrying out the method for electric arc treatment of parts, comprising at least one electrode mounted on a holder connected by means of a current supply member to one lead of the power supply having the other lead connected to a part being treated, and an arc excitation system, according to the invention, is provided with at least one means for creating on the surface of the part and/or at least one electrode during arcing, areas with electrical potential which is higher and/or lower than the potential of the rest of the surface and for moving these areas along said surface, said means being connected to the power supply, and with a means for limiting movement of plasma of the arc discharge to the treatment zone of the part and/or the working surface of at least one electrode.

The provision of said means for creating, during arcing, areas with a higher and/or lower electrical potential with respect to the potential of the rest of the surface on the surface of the part and/or electrode and for moving these areas along said surface (or surfaces), as well as a means for limiting movement of plasma of the arc in the apparatus according to the invention ensures movement of the extremum potential of the electrode spots of the arc to follow up said areas and eliminates movement of these spots to other areas of the part and/or electrode so as to ensure treatment of a

selected zone of the part in accordance with a preset program.

It is preferred that the means for creating, during arcing, areas with a higher and/or lower electric potential on the surface of the part and for moving these areas along said surface be in the form of at least two current supply members connected to different portions of the part and a switch of these current supply members which is capable of ensuring permanent contact between the part and the power supply.

The means for creating, during arcing, areas with higher and/or lower electrical potential on the surface of the electrode and for moving these areas along said surface may be in the form of at least two current supply members connected to different areas of the electrode, and a switch of these current supply members which is capable of ensuring permanent contact between the electrode and the power supply.

This construction of the above-described means is very simple and does not call for additional energy expenditures for movement of the electrode spots.

It is preferred that the current supply members be connected to the part and/or electrode symmetrically with respect to the treatment zone of the part and/or working surface of the electrode.

If such current supply members are switched at one and the same rate, uniform and directional movement of the arc spots can be achieved along the treatment zone of the part and/or the working surface of the electrode so as to ensure uniform treatment of the part with the arc discharge.

The current supply member switch may be in the form of a transformer and rectifiers connected between the current supply members and end leads of the secondary winding of the transformer having its middle tap to which is connected a respective lead of the power supply, and an a-c power supply connected to the primary winding of the transformer.

During operation of this switch, said rectifiers alternately become conductive at respective half-cycles of the a-c voltage so as to carry out the automatic electronic switching of the current supply members without breaking the electric circuit. This switch is preferably used in combination with standard d-c power supplies, e.g., welding rectifier converters.

The electrode and the part can also be connected to a polyphase a-c power supply or to a polyphase alternating current converter, and the number of current supply members in this case should be equal to, or m ltiple of the number of phases of such olyphase a-c power supply or polyphase alternating current converter, the current supply member switch being in the form of rectifiers connected between each line output of said polyphase a-c power supply or polyphase alternating current converter and at least one current supply member.

This connection of the apparatus allows said rectifiers to be used both for rectification of alternating current and for automatic electronic switching of the current supply members without breaking the electric circuit so that not only the desired switching of the current supply members is ensured, but the number of components of the electric circuitry is reduced and reliability of the apparatus in operation is improved.

If the apparatus has a number of current supply members which is multiple of the number of phases of an a-c polyphase power supply or polyphase alternating corrent converter, it is preferred that they be connected into groups the number of which is equal to the number of phases of said alternating polyphase power supply or polyphase alternating current converter, the current supply members of each group being distributed along the treatment zone of the part and/or along the working surface of the electrode.

This connection of the current supply members allows the number of simultaneously switched electrodes or current supply zones of the part (or electrode) to be increased by several times so as to achieve the same reduction of the size of the treatment zone of the part being treated.

In case the apparatus has at least three current supply members it is preferred that they be positioned with respect to the treatment zone of the part or along the working surface of the electrode in a sequence corresponding to the sequence of voltage increase at the line outputs of the polyphase a-c power supply or polyphase alternating current converter connected to these current supply members.

This facility provides conditions for a gradual movement of electrode spots from one current supply zone of the part (or electrode) to another or from one electrode to another so as to ensure treatment of the part in accordance with a coordinate variation program set forth by the polyphase a-c power supply.

In various embodiments of the apparatus, the part or the electrode can be connected either to the neutral point of the polyphase a-c power supply of polyphase alternating current converter or to its line outputs via auxiliary rectifiers which are connected in opposition to the main rectifiers.

The embodiment in which the part or the electrode is connected to the neutral point of said power supply or converter is simpler, but the embodiment involving their connection to the line outputs via the auxiliary rectifiers ensures lower fluctuations of the discharge current so as to enhance

stability of the arc. The choice of the options depends on specific application.

It is preferred that the means for limiting movement of plasma of the arc discharge to the treatment zone and/or the working surface of at least one electrode be made in the form of screens insulated from the electric circuit, positioned in a spaced relation to the part and/or electrode, and protecting portions of the part that do not have to be treated and/or non-working surface of the electrode, at least those portions of the screens which are located adjacent to the treatment zone of the part and/or working surface of the electrode being either made of a high-temperature material or positively cooled.

This construction of the above-described means is the simplest are and, at the same time, very efficient from the functional point of view so that it is preferred for the practical implementation of this invention.

I_n specific applications of the invention, the form and position of the screens may vary. Thus, in treating parts in the form of bodies of revolution and in case the electrodes are in the form of truncated cones having coaxial holes, the screens are preferably mounted in these holes. In case of the two-sided treatment of strip rolled stock, its is preferred that the screens be positioned between the electrodes located on either side of the strip rolled stock being treated, the screens being installed in the spaces between the electrodes and the surface of the rolled stock being treated.

This position of the screens ensures the best performance in such applications.

The above problem is also solved by that an apparatus for carrying out the method for electric arc treatment of parts, comprising at least one electrode mounted on a holder, connected by means of a current supply member to one lead of a power supply or a polyphase alternating current converter having its second lead connected by means of at least one other current supply member to a part being treated, and an arc excitation system, according to the invention, is provided with a means for compression or partial restriction of the area of the arc discharge in the space between the part being treated and the electrode and with a mechanism for relative movement of the part and said means for compression or partial restriction of the area of the arc discharge.

The provision of said means for compression or partial restriction of the area of the arc discharge in the space between the part being treated and the electrode and the mechanism for relative movement of the part and said means allows the desired treatment of the part to be carried out in accordance with a preset program owing to the movement of the electrode spots along the part to follow up the area of compression or partial restriction of the arc.

It is preferred that the means for compression of the area of the arc discharge in the space between the part being treated and the electrode be in the form of a screen positioned between the electrode and the part and having an opening corresponding to the area of the part being treated.

This construction of the apparatus is most simple and can be easily implemented.

It is preferred that the current supply member be connected to the part on the side opposite to the arc excitation zone and that the means for partial restriction of the area of the arc discharge in the space between the part being treated and at least one electrode be in the form of at least one screen positioned between the electrode and the part being treated so as to cover a portion of the part between the treatment zone and the current supply member.

The electrode spots of the arc are thus shifted along the part towards the current supply member and arc concentrated adjacent to the boundary of the screen, and, during the relative movement of the part being treated and the screen, these spots carry out the desired treatment of the desired surface of the part.

Brief Description of the Drawing

The invention will now be described with reference to specific embodiments illustrated in the accompanying drawings, in which:

Fig. 1 schematically shows an apparatus illustrating the first embodiment of a method for electric arc treatment of parts according to the invention;

Fig. 2 schematically shows an apparatus illustrating an example of the second embodiment of a method for electric arc treatment of parts according to the invention;

Fig. 3 shows an apparatus illustrating another example of the second embodiment of a method according to the invention;

Fig. 4 is a sectional view taken along line IV-IV in Fig. 3;

Fig. 5 schematically shows an apparatus illustrating the third embodiment of a method for electric arc treatment of parts according to the invention;

Fig. 6 schematically shows an apparatus illustrating the step of positive movement of electrode spots of the arc along the part by switching the electrodes;

Fig. 7 is a sectional view taken along line VII-VII in Fig. 6;

Fig. 8 schematically shows an apparatus for electric arc treatment (cleaning) of elongated

parts according to the invention;

Fig. 9 is a view taken along arrow A in Fig. 8;

Fig. 10 is a view taken along arrow B in Fig. 8;

Fig. 11 schematically shows an apparatus for electric arc treatment (cleaning) of strip rolled stock according to the invention;

Fig. 12 illustrated the construction of an electrode unit of the apparatus shown in Fig.11;

Fig. 13 is a view taken alone arrow C in Fig. 12;

Fig. 14 schematically shows an apparatus for electric arc treatment (cleaning) of strip rolled stock according to the invention;

Fig. 15 illustrated the construction of an electrode unit of the apparatus shown in Fig. 14;

Fig. 16 is a view taken along arrow D of the electrode unit shown in Fig. 15;

Fig. 17 schematically shows an apparatus for electric arc vaporization with an elongated consumable cathode of a non-closed configuration, according to the invention;

Fig. 18 shows an apparatus for electric vaporization having and endless consumable cathode;

Fig. 19 shows an apparatus for electric arc vaporization designed for deposition of coatings to the outer surface of elongated parts;

Fig. 20 is a sectional view taken along line XX-XX in Fig. 19;

Fig. 21 schematically shows an apparatus for welding and cutting in vacuum with movable arc according to the invention;

Fig. 22 is a sectional view taken along line XXII-XXII in Fig. 21;

Fig. 23 schematically shows an apparatus for electric arc treatment (cleaning) of the inner surface of the inner surface of hollow parts (pipes) according to the invention;

Fig. 24 is a sectional view taken along line XXIV-XXIV in Fig. 23.

Embodiments of the Invention

Let us discuss the gist of various embodiments of a method for electric arc treatment of parts which will be discussed in greater detail in connection with the description of apparatuses for carrying out the method.

In its first embodiment, a method for electric arc treatment of parts resides in the fact that a part 1 to be treated (Fig. 1) is placed into a vacuum chamber (not shown in the drawing), and part 1 and at least one electrode 2 surrounding part 1 arc connected to a power supply 3. An arc discharge is excited under a pressure of a medium below 10 Pa between part 1 and electrode 2 in the mode of a drooping portion of the volt-ampere characteristic of the arc or, which is an equivalent, a power supply 3 is used which has a drooping external volt-ampere characteristic. Arc excitation is effected by injecting a small amount of plasma into the interelectrode gap to form a conducting path between part 1 and electrode 2, e.g., by opening up the contact between electrode 2 and an auxiliary firing electrode 4 having its current limited by means of a resistor 5. The arcing mode is set up by controlling discharge current, e.g., by means of a ballast rheostat 6.

During arcing, a difference of potential of electric field equal or close to zero is created on the surface of the treatment zone of part 1 and on the working surface of electrode 2. This can be achieved by connecting part 1 to power supply 3 by means of two current supply members 7 and 8 connected to part 1 symmetrically with respect to its treatment zone, electrically connected to each other and to one lead of power supply 3 and by connecting electrode 2 to power supply 3 by means of similar symmetrically connected current supply members 9 and 10.

In addition, the area of movement of plasma of the arc is limited to the treated zone of part 1 e.g., by means of screens 11 and 12 and to the working surface of electrode 2, e.g., by means of a screen 13.

Electrode, especially cathode spots of the arc at a pressure of a medium below 10 Pa, including the purely vacuum discharge, continually spontaneously move along the surface of part 1 and electrode 2 and, if the arc is excited in the mode of a drooping portion of its volt-ampere characteristic, or if the discharge is supplied by a power supply 3 having a drooping external characteristic, mobility of the spots is substantially enhanced. This phenomenon, which is most frequently undesired in case of a low-pressure arc, is used in the method according to the invention to achieve the useful result - uniform or otherwise programmed treatment of the part surface.

In this embodiment of the method, owing to the creation on said surfaces of a difference of potentials of electric field close to zero, a substantially equal probability of the occurrence of the electrode spots of the arc in all areas of the treatment zone of part 1 defined by screens 11 and 12 is ensured. The electrode spots move chaotically along the whole surface of the zone to ensure its uniform treatment.

The embodiment of the method is characterized by extreme simplicity of an apparatus for its implementation, and electrode 2 may be in the form of the inner surface of the vacuum chamber. However, in case this embodiment is used, it is necessary to bear in mind that high uniformity of treatment cannot be ensured in all cases and, as a rule, it can be achieved with symmetrical position of parts located adjacent to the treatment zone, the parts being made of nonmagnetic materials. In

particular applications of this embodiment of the method, it is necessary either to create a difference of potentials of electric field equal, or close to zero as described above simultaneously on the surface of the treatment zone of part 1 and on the working surface of electrode 2, or, depending on specific application, only on the surface of part 1 or only on the working surface of electrode 2.

If the above-described first embodiment of the method is not capable of ensuring the desired uniformity of treatment for some reason or, if, on the contrary, different portions of the part should be treated in different manners, other embodiments of this method described below can be used.

A method for electric arc treatment of parts in the second embodiment differs from that described above in that, during arcing, a difference of potentials of electric field other then zero is created on the surface of a part 14 (Fig. 2), and areas with the highest or lowest potential are directionally moved in accordance with a preset program depending on polarity of the electric arc treatment. It should be noted that the electrode spots of the arc move directionally to follow up these areas of extremum potential along the surface of part 14 so as to ensure treatment of part 14 in accordance with a preset program, and a casing 15 of a vacuum chamber along which the discharge is sufficiently uniformly distributed over the whole inner surface is used as an electrode (cathode).

Another application of the second embodiment of the method according to the invention differs from that described above by the fact that, during arcing, a difference of potentials of electric field other then zero is created on the surface of at least one electrode 16 (Figs. 3,4), and areas with the highest or lowest potential are directionally moved in accordance with a preset program depending on polarity of the electric arc treatment. It should be noted that the electrode spots of the arc will directionally move to follow up these areas of extremum potential along the surface of electrode 16 (Figs. 3,4), and the surface of the treatment zone of a part 17, depending on specific application, is either sufficiently uniformly surrounded by a plasma cloud, or the electrode spots of the arc move directionally therealong to follow up the electrode spots moving along electrode 16.

A combination of the above-discussed cases of the second embodiment of the method for electric arc treatment is also possible, wherein, during arcing, said areas of extremum potential on the surfaces of both the electrode and part are moved to ensure the positive movement of the electrode spots of the arc on both surfaces. In practice this can be used very rarely since a more complicated apparatus would be required to carry out such method.

As mentioned above, it is most preferred that a difference of potentials of electric field be provided by supplying electric current to areas of part 14 (Fig. 2) of electrode 16 (Figs. 3,4) remote from the zone in which electrode spots of the arc are located, and that movement of the areas of the highest and/or lowest potential of electric field be effected by varying position of current supply zones on part 14 (Fig. 2) or electrode 16 (Figs. 3,4), e.g., by means of current supply members 18, 19, 20 (Figs. 2,3) connected to different portions of part 14 (Fig. 2) or electrode 16 (Figs. 3,4) and by means of a switch 21 (Figs. 2,3) of these current supply members which is capable of ensuring permanent contact between part 14 (Fig. 2) and electrode 16 (Figs. 3,4) on the one hand and power supply 3 (Figs. 2,3,4) on the other (a switch with electromechanical contacts is shown here for the sake of clarity, but highly reliable electronic switches will be described below).

The gist of this step of providing and moving the areas of extremum electric potential ensuring movement of the electrode spots of the arc is in the following. Supplying electric current to areas of part 14 (Fig. 2) or electrode 16 (Figs. 3,4) remote from the zone of location of the electrode spots of the arc causes current to flow through parts 14 (Fig. 2) or electrode 16 (Figs. 3,4) whereby the equilibrium distribution of charges on their surface is brloken, and a tangential component of intensity of electric field emerges. The resulting electric field on the surface of part 14 (Fig. 2) or electrode 16 (Figs. 3,4) as well as magnetic field of the electric current flowing therein act upon the electrode spots of the arc discharge thus causing them to move towards areas of the highest and lowest electric potential depending on polarity of the electric arc treatment. If now, without breaking the electric circuit, the current supply members 18, 19, 20 (Figs. 2,3,4) are switched by switch 21 to change the position of current supply zones on part 14 (Fig. 2) or electrode 16 (Figs. 3,4), areas of extremum potential will move on the surface of the part and electrode, and the electrode spots of the discharge will follow suit. Depending on application, the time during which each of the current supply members 18, 19, 20 is energized may be the same or different so as to treat part 14 (Fig.2) or part 17 (Fig. 4) in accordance with a preset program.

Both the above-described embodiments of the method according to the invention may be used for treating elongated parts. For that purpose, part 1 (Fig. 1) or part 17 (Figs. 3,4) should be moved relative to electrode 2 or electrode 16 (Figs. 3,4), respectively, and/or electrode 2 (Fig. 1) or electrode 16 (Figs. 3,4) should be moved relative to part 1 (Fig. 1) or part 17 (Fig. 4), respectively, so as to ensure uniform or otherwise movement-pro-

grammed electric arc treatment of elongated parts along the whole length thereof.

The third embodiment of the method differs from those described above by the fact that an area occupied by arc discharge plasma is positively compressed or partly restricted in the space between the part being treated and at least one electrode, and this area is moved in accordance with a preset program with respect to the part and/or the part is moved with respect to this area of the arc discharge.

The positive compression of the area occupied by plasma of the arc discharge in the space between a part 22 being treated (Fig. 5) and an electrode 23 (a so called "discharge column") is preferably carried out by means for compression of this area of the arc discharge in the form of a screen 24 positioned between electrode 23 and part 22 and having an opening 25 corresponding to a treatment zone 26 of part 22, and movement of this area of the arc with respect to part 22 and/or movement of part 22 with respect to this area is carried out by means of a mechanism 27 for their relative movement which in this case is connected to screen 24.

This step of the electric arc treatment is based on the fact that when the electrode spots of the arc move beyond the limits of treatment zone 26 of part 22 corresponding to the shortest distance from electrode 23 to part 22 and to opening 25 of screen 24, the length of the discharge column increases to result in its increased resistance and to impair conditions for arcing. The electrode spots will thus either move back to portion 26 or disappear. In the latter case, new electrode spots of the arc are formed in zone 26 through splitting of the available electrode spots. During the relative movement of screen 24 and part 22 by means of mechanism 27, zone 26 corresponding to the shortest distance from electrode 23 to part 22 moves along part 22. On the other hand, since, for the above-mentioned reasons, the probability that the electrode spots will occur on this portion is much greater, they will move to follow up this portion so as to ensure the electric arc treatment of part 22 in accordance with a program set up by mechanism 27.

An example of partial restriction of the area of the arc discharge in the space between the part and electrode is shown in Figs. 3,4 and 6,7 where such restriction is achieved by means of a screen 28 (Fig. 4) positioned between electrode 16 and part 17 of a screen 28' (Fig. 7) positioned between electrodes 29, 30, 31 (Figs. 6, 7) and part 17 to cover a portion of this part 17 between the treatment zone and a current supply member 32 of the part, the current being supplied to part 17 on the side opposite to the side of arc excitation. The electrode spots of the arc move along paint 17 towards current supply member 32 and concentrate adjacent to the boundary of screen 28, 28', and in case of the relative movement of part 17 and screen 28 and electrode 16 (Fig. 4) or screen 28' (Fig.7) and electrodes 29, 30, 31 (Figs. 6, 7) the necessary treatment of the desired surface of part 17 is achieved by these spots.

Another approach to the positive movement of the electrode spots of the arc used in this method resides in the fact that, in case at least two electrodes are used, the value of electric current is lowered, or the electric current is interrupted in accordance with a preset program in the circuit of at least one electrode, the current in the circuit of the electrodes remaining unchanged or being increased. Current can be interrupted in this manner in the circuit of electrodes 29, 30, 31 (Fig.6) by means of a switch 21 of current supply members 33, 34, 35 of these electrodes 29, 30, 31 as described above, and current can be increased in the circuit of these electrodes 29, 30, 31 in the most simple manner by means of rheostats (not shown in the drawing) connected in series with current supply members 33, 34, 35.

With such interruption or variation of current in the circuit of electrodes 29, 30, 31 the direction of electric field in the discharge gap is reversed so as to cause the directional movement of the electrode spots along part 17 rotation of such spots along the perimeter of part 17 in a zone adjacent to screen 28' in the example shown in Figs. 6,7).

In all the above-described examples of implementation of the method according to the invention, a part being treated can be connected either to negative or to positive terminal of power supply 3, except for examples shown in Figs. 2 and 6,7 in which it is preferred that part 14 (Fig. 2) or part 17 be connected to the negative terminal of power supply 3. This is due to the fact that with an opposite polarity, erosion of the casing of vacuum chamber 15 (Fig. 2), which functions as electrode, will take place under the action of the cathode spots, and in the example shown in Figs. 6,7, arc breakage can occur during switching of electrodes 29, 30, 31, and the probability of such breakage increases with an increase in the switching rate since the cathode spot of the arc may not have time to form on the switched electrodes 29, 30, 31, and this spot is decisive for discharge to occur.

As mentioned above, the negative polarity of the part is preferably used for its cleaning, descaling and deburring and for vaporization of the material of the part and the positive polarity is preferably used for heating, welding, cutting, and polishing of parts.

The process of electric arc cleaning is based on the fact that the cathode spots of the arc are

moved along the surface of the part being treated, the temperature in the area of the spots being as high as 3000 to 5000 °C. The cathode spots move at a speed of 10^{-2} to 10^{2} m/s depending on the kind of scale and contamination of the surface of the part, and they remove scale and vaporize it as they move so as to clean the surface. Deburring and removal of minos irregularities from the surface of parts occurs in the same manner.

When the electric arc cleaning is carried out as described in any of the above- or below-described examples, it is preferred that the arc current and treatment time during the treatment be maintained at a level at which the specific energy consumption should be within the range from 0.1 to 0.8 kW-h/m^{2} μm so as to ensure complete removal of scale from the surface being cleaned without appreciable erosion of the part being treated and with a high enough productivity of the process.

The process of the electric arc vaporization of materials is based on generation of plasma jets in the cathode spots of a vacuum arc. Unlike the electric arc cleaning, the cathode spots of the arc here move along the clean surface of the cathode made of a material being vaporized, and a medium necessary for firing the discharge is formed owing to the erosion of the electrode. The resulting flow of metal plasma is directed to a substrate where it is condensed to form a coating. With a typical coating deposition rate of 10^{-2} to 5×10^{-1} μm/s, the method ensures a high degree of ionization vapour from 20 to 100% depending on the cathode material , and an energy of ions is between 10 and 100 eV which ensures enhanced adhesive properties of the coatings in comparison with conventional methods of thermal vaporization and cathode sputtering. Coatings of both metals and alloys can be deposited, and supplying reagent gases (nitrogen, methane and the like) allows layers of complicated composition to be deposited with the use of direct synthesis plasmochemical reactions.

Processes occurring during welding and cutting of parts using the method according to the invention are similar to those occurring during shielded electric arc welding and cutting. The difference resides in the fact that the electrode spots of the arc are moved by using the techniques described above, rather than by moving the electrode as is the case in the prior art methods. The advantages of the method according to the invention resides in that parts are treated in vacuum so as to completely avoid reaction of incadescent material of the part with a medium thus enhancing quality of treatment (welding) of parts made of active materials such as titanium and its alloys.

Specific embodiments of apparatuses for carrying out the above-described embodiments of the methods will now be described.

An apparatus for electric arc treatment, preferably, for cleaning of elongated parts, e.g., bars comprises at least two coaxially mounted and positively cooled electrodes 36 and 37 (Fig. 8) having coaxial holes for receiving part 1 to be treated. Electrodes 46 and 37 are made in the form of truncated cones having their smaller bases facing towards each other, the angle between the generant and height of the cones reanging from 35 to 85 °. Screens 38, 39 are positioned between part 1 and electrodes 36 and 37 in holes of electrodes 36, 37, which are made of a high-temperature material and which function as the means for limiting movement of plasma of the arc discharge to the zone of treatment of part 1 and working surfaces of electrodes 36 and 37.

The apparatus also comprises a means for creating, during arcing, a difference of potentials of electric field equal or close to zero on the surface of the treatment zone of part 1, which is in the form of two current supply members 7 and 8 connected to part 1 symmetrically with respect to the treatment zone, electrically connected to each other and connected to the negative terminal of power supply 3, and a means for creating a difference of potentials of electric field equal or close to zero on the working surface of electrodes 36, 37 in the form of current supply members 40, 41, 41 (Fig. 9) and 43, 44, 45 (Fig. 10) electrically connected to one another and connected to the positive terminal of power supply 3 (Fig. 8) and to the larger bases of the truncated cones of electrodes 36 and 37 symmetrically with respect to their working surface, the current supply members 40, 41, 42 being connected to electrode 36 with an offset of one-half-the distance between current supply members 43, 44, 45 towards electrode 37 as shown in Figs. 9 and 10. Current supply members 40, 41, 42 also function as holders of electrode 36 and current supply members 43, 44, 45 are used as holders of electrode 37.

Electrodes 36, 37 (Fig. 8) are mounted for movement with respect to each other for controlling the width of the treatment zone, and part 1 is capable of reciprocating during the treatment by means of a mechanism 46. At least the portion of part 1 being treated, electrodes 36, 37, firing electrode 4, and screens 38, 39 are mounted inside a vacuum chamber (not shown in the drawing).

The apparatus is used for the implementation of the first embodiment of the method according to the invention and functions in the following manner.

With a pressure of a medium in the chamber below 10 Pa, an arc discharge is initiated between electrodes 36, 37 (Fig. 8) and part 1 being treated by means of firing electrode 4, the discharge current being adjusted by means of ballast rheostat 6.

The cleaning process is based on the fact that

the cathode spots of the arc move along the surface of part 1, and temperature at these spots is as high as 3000 to 5000°C. The cathode spots move at a speed of 10^{-2} to 10^{2} m/s depending on the kind of scale and contamination of the surface of part 1 and remove scale and vaporize it as they move thus cleaning the surface.

Owing to the symmetric supply of current to part 1 and electrodes 36 and 37, even during arcing, a difference of potentials of electric field is maintained on their surface which is close to zero so as to ensure the substantially identical probability of the occurrence of the cathode spots in all areas of the treatment zone of part 1 located between electrodes 36, 37 and defined by screens 38 and 39. The cathode spots move in a random manner over the whole surface of the treatment zone so as to ensure uniform cleaning of part 1 in this zone. For cleaning the whole surface of part 1, it is linearly moved with respect to electrodes 36 and 37 by means of feed mechanism 46.

Owing to the conical shape of the working surface of electrodes 36 and 37, products of erosion of part 1 being cleaned are substantially completely removed from the area of the arc gap, and only a minor fraction of these products is deposited on the working surface of electrodes 36, 37 so as to enhance reliability and prolong service life of the apparatus. The value of the angle of inclination of the cone generant ranging from 35 to 85° is chosen by way of experiments bearing in mind the angle of emission of the eroded fraction with the least probability of its deposition on the anode while retaining high stability of arcing. With the angles between the generant and height of the cone below 30° the arc can break, and with angles in excess of 85°, the major fraction of the eroded scale will be deposited on electrodes 36 and 37 so to result in changes in conditions of arcing.

It has been found by way of experiments that connecting current supply members 40, 41, 42 to electrode 36 with an offset at one-half the distance between current supply members 43, 44, 45 towards electrode 37 as shown in Figs. 9, 10 results in a zig-zag movement of the cathode spots of the arc along the perimeter of part 1 so as to enhance uniformity of treatment, lower probability of fusion of the part during its cleaning, and improve quality of cleaning in dealing with parts having a large surface area, in particular, spindles of cotton harvesters.

The best cleaning quality is ensured by making choice of the arcing conditions, distance between electrodes 36 and 37, and speed of movement of part 1.

Descaling of steel bars of 12 mm diameter and spindles of cotton harvesters in the form of a tube 630 mm long with four rows of teeth on the outer surface was carried out on commercial scale. Good quality of cleaning was achieved with an arc current of 250 A, speed of the part being cleaned of 30 to 50 mm/s, and distance between the electrodes of 30 to 35 mm.

An apparatus for electric arc treatment, preferably for cleaning of strip rolled stock is shown in Figs. 11, 12, 13. The apparatus comprises a vacuum chamber 47 (Fig. 11) accommodating in its casing electrodes 48 and firing electrodes 4 and 4'. Electrodes 48 are rigidly mounted on a common holder (not shown in the drawings). The end parts of vacuum chamber 47 incorporate an inlet lock system 49 and an outlet lock system 50.

Vacuum chamber 47 is connected, by means of pipelines 51, to a vacuum pump 52 of a vacuum system. Driven pull rollers 53 and 54 are mounted at the inlet and outlet of lock systems 49 and 50, respectively, and are designed for transporting (by tension) strip stock 55 with respect to electrodes 48.

The apparatus is also provided with a means for creating, during arcing, a difference of potentials of electric field equal, or close to zero on the surface of the treatment zone of rolled stock 55, which is in the form of current supply members 7' and 8' connected the rolled stock 55 being treated symmetrically with respect to the treatment zone, electrically connected to each other and connected to the negative terminals of power supplies 3 having their positive terminals connected to electrodes 48.

Electrodes 48 are made in the form of at least one pair (four pairs in this embodiment) of mirror-parallel prisms having their facets facing each other which are inclined at an angle of 35 to 85° and which have their working surfaces positioned symmetrically with respect to the axis of strip stock 55 and in parallel with this axis as shown in Fig. 13. If there are two or more pairs of electrodes 48 in the form of mirror-parallel prisms in the apparatus, they are mounted along the path of movement of strip rolled stock 55 (Fig. 12).

If its is necessary to carry out the two-sided treatment (cleaning) of rolled stock, the apparatus is provided with auxiliary electrodes 56 (Figs. 11, 12, 13) mounted symmetrically with respect to the main electrodes 48 on the opposite side of rolled stock 55 and connected to power supplies 3 similarly to electrodes 48.

Positively cooled screens 57 are designed for limiting movement of plasma of the arc discharge to the treatment zone of rolled stock 55 and to the working surface of electrodes 48 and 56. With the two-sided treatment (cleaning) fof rolled stock, these screens 57 should be preferably placed between electrodes 48 and 56 mounted on the opposite sides of rolled stock 55 (Fig. 13). It is

preferred that screens 57 be secured to the outer facets of electrodes 48 and 56 and insulated therefrom by means of insulating sleeves 58 (Fig. 13). Hoppers 59 having vacuum-tight gates 60 are provided in the bottom part of the casing of vacuum chamber 47.

The apparatus functions in the following manner. Strip stock 55 (Fig. 11) is fed by means of pull rollers 53 and 54 to vacuum chamber 47 and is positioned under tension in the space between electrodes 48 and 56. Vacuum pump 52 reduces pressure to a level below 10 Pa in vacuum chamber 47 through pipeline 51. Power supply 3 is turned on, and an arc discharge is initiated between electrodes 48, 56 and strip stock 55 by means of firing electrodes 4 and 4'. When the discharge is initiated, pull rollers 53 and 54 start transporting strip stock 55 through vacuum chamber 47.

As shown by investigations, the exposure to the arc discharge results in a for action of scale being reduced to pure metal, the rest of the scale being vaporized and deposited on the walls of chamber 47. This fraction of the scale is removed by brushes to the bottom of chamber 47, into hoppers 59 having special lock chambers with gates 60, and is transferred outside the chamber without loss of tightness of chamber 47. As regards the released gas, it is removed by continually operating pumps. Therefore, the provision of electrodes 48, 56 in the form of truncated mirror-positioned prisms brings solution simultaneously to two problems: on the one hand it allows eroded fraction to leave the arcing zone unobstructed and do not allow it to be deposited on electrodes 48, 56 (the range of the prism facet inclination angle was discussed above) and, on the other hand, this facility provides uniform electric field adjacent to the cathode surface, i.e., on strip stock 55 being cleaned so as to create conditions for uniform distribution of the cathode spots on this surface to ensure high-quality cleaning of the surface. The number of cathode spots is proportional to the discharge current, but it is not infinite. With a certain current, which can be regarded as critical current, the value of which depends on structural features of the apparatus, material of the rolled stock and pressure of the medium, a change in the arc discharge mode occurs, and the arc discharge changes from the arc with travelling spots to the arc with concentrated spots, one or both electrodes 48 being fused. This phenomenon limits the maximum width of strip stock 55 which allows a sufficiently uniform distribution of the cathode spots to be achieved. With an increase in the width of rolled stock 55, the arc current should be increased so as to obtain the sufficient number of cathode spots. However, this is only possible within certain limits because of fusion of electrodes 48 with currents in excess of critical current. The arc current cannot be in definitely lowered either in carrying out the treatment of narrow strip stock 55 since the arc will be interrupted. It has been found by way of experiments that the apparatus according to the invention can successfully clean strip stock of 20 to 100mm wide.

The above-described apparatus can be used for cleaning strip rolled stock by electric arc discharge in vacuum in dealing with metal strips of ferrous and non-ferrous metals and alloys with high-quality and uniform cleaning of both surfaces of strip stock since power supplies 3 can work independently.

Strip stock 55 treated by electric arc discharge in vacuum has good vendible appearance; its corrosion resistance is enhanced and surface area is increased which is especially important for coating deposition.

If it is necessary to treat (clean) rolled stock of a width greater than 100 mm, use is made of an apparatus shown in Figs. 14, 15, 16. This apparatus differs from that described above by the fact that electrodes 61 and 62 in the form of mirror-parallel prisms are installed pairwise symmetrically with respect to a plane 63 (Fig. 16) drawn at right angles with respect to the direction of movement of strip stock 64 through the middle of the treatment zone of this rolled stock 64, the adjacent electrodes 61 being mounted with respect to each other for covering the treatment zone of each of the arc discharges by the treatment zone of at least one other discharge, and screens 65 and 66 (Figs. 14, 15, 16) are positioned in spaces between electrodes 61, 62 and the surface being treated of strip stock 64.

This construction of the apparatus allows cleaning of strip rolled stock of any section to be carried out at a desired speed owing to the parallel and consecutive coverage of the surface being treated during movement of the rolled stock.

We have discussed the apparatuses provided mainly for electric arc cleaning of parts. However, as mentioned above, the method according to the invention may be not least effectively used for vaporizing various materials with the aim of depositing coatings. Examples of such use of the method are given in Figures 17, 18, 19, 20 which show apparatuses for carrying out the second embodiment of the method.

An apparatus for electric arc treatment, namely for vaporizing shown in Fig. 17 differs from the apparatus described above and shown in Fig. 2 by the fact that it has part 14 (Fig. 2) replaced by a consumable cathode 67 (Fig. 17) of a material being vaporized in the form of a planar bus opposite to which is positioned an elongated support

68 to be plated, and the means for creating, during arcing, areas with a lower electric potential in comparison with the potential of the rest of cathode 67 on the surface of cathode 67 and for moving these areas along this surface comprises two current supply members 18 and 20 connected to the opposite ends of cathode 67 which also function as the cathode holder and an electronic switch of current supply members 18 and 20 in the form of a transformer 69 and rectifiers 70 and 71 connected between current supply members 18, 20 and end leads of the secondary winding of transformer 69 having its middle tap to which is connected the negative terminal of power supply 3, and an a-c power supply 72 connected to the primary winding of transformer 69.

This apparatus functions in the following manner. With a pressure of the medium below 10^{-2} Pa, which is necessary to rule out reaction of the material being vaporized with residual gases, an arc discharge is initiated by means of firing electrode 4 between casing 15 (anode) and consumable cathode 67 which occurs in vapour of the material of consumable cathode 67 and concentrates on the working surface of this cathode by means of screen 11.

Arc discharge current flowing through cathode 67 from the cathode spot of the arc towards current supply member 18 or 20 whichever is connected at a given moment to power supply 3 creates on the surface of cathode 67 a difference of potentials of electric field whereby the cathode spots of the arc are shifted towards the zone of a lower potential. Rectifiers 70 and 71 alternately become conductive in alternative half-cycles of the a-c voltage of power supply 72 so as to ensure the automatic switching of current supply members 18, 20 of cathode 67 thereby reversing direction of electric field on the surface of cathode 67 and ensuring reciprocation of the cathode spots along cathode 67 at a rate corresponding to frequency of the a-c voltage.

Thus uniform erosion of the material of cathode 67 is ensured with uniform thickness of the coating along the length of support 68.

To produce uniform coatings along the perimeter of support 68, the support is caused to rotate about its axis, and for metal plating of coiled stock, such coiled stock is uncoiled over cathode 67. If necessary, this apparatus can work in any position in space.

Fig. 18 shows an apparatus for electric arc treatment, more particularly, for vaporization, in which a cathode 73 is made in the form of a ring of a material to be vaporized, and the anode, similarly to the above-described apparatus, is in the form of a casing 74 of a vacuum chamber which accommodates cathode 73 and a support 75 to be metal-plated. The apparatus is connected to a power supply of polyphase alternating current converter, and the means for creating, during arcing, areas with a lower electric potential with respect to the potential of the rest of the surface of cathode 73 on the surface of cathode 73 and for moving these areas along this surface comprises current supply members 77, 78, 79 the number of which corresponds to the number of phases of the power supply a-c voltage converter 76, and an electronic switch of these current supply members in the form of rectifiers 80, 81, 82 connected between each line output of converter 76 and a respective current supply member, the cathodes of rectifiers 80, 81, 82 being connected to converter 76, and the neutral point of the converter being connected to casing 74 (anode) of the apparatus. Current supply members 77, 78, 79 are connected to various portions of cathode 73 spaced along its perimeter and also function as holders of this cathode 73. Owing to the fact that rectifiers 80, 81, 82 are connected to cathode 73 with their like leads, electric current can flow in this embodiment only in the circuit casing 74 (anode) - cathode 73 - current supply members 77, or 78, or 79 whichever has its circuit with the lowest potential at a given moment - rectifier 80, or 81, or 82 connected in series with such current supply member - converter 76 - casing 74 (anode).

In this apparatus, cathode spots of the arc directionally move along the vaporizing surface of cathode 73 to follow up the area of the lowest potential on this electrode in accordance with a program of variation of coordinates set up by a-c converter 76. With a symmetrical polyphase (three-phase in this embodiment) system and symmetrical position of current supply members 77, 78, 79, uniform movement of the cathode spots along the perimeter of cathode 73 and uniform vaporization of cathode material are achieved.

Owing to the ring configuration of cathode 73 in this apparatus, better uniformity of the film thickness is achieved on a much larger surface area in comparison with the use of disc-shaped small-diameter cathodes in conventional electric arc vaporizers.

An apparatus shown in Figs. 19, 20 differs from that shown in Fig. 18 by the fact that its anode is in the form of a support 83 to be metal-plated (Figs. 19, 20) which is connected to the cathodes of auxiliary rectifiers 84, 85, 86 connected to line outputs of converter 76 in opposition to the main rectifiers 80, 81, 82. A consumable ring cathode 87 has the inner vaporazing surface, and current supply members 88, 89, 90, 91, 92, 93 which also function as holders of cathode 87 are connected symmetrically to its perimeter, the number of the current supply members corresponding to two times the number of phases of the a-c power

supply voltage (in a general case, the number of current supply members is a multiple of the number of phases). Current supply members 88 and 91, 89 and 92, 90 and 93 are electrically connected into groups the number of which is equal to the number of phases of converter 76, and each group is connected to different line outputs of this power supply via rectifiers 80, 81, 82. Current supply members 91, 92, 93 are connected along the perimeter of the electrode in series downstream current supply members 88, 89, 90, all current supply members 88,89,90,91,92,93 being positioned one after another in a sequence of increase in voltage at line outputs of converter 76 connected to these current supply members 88,89,90,91,92,93. A high-temperature screen 94 (Fig.20) is positioned in a spaced relation to the outer lateral and end faces of cathode 87 to ensure concentration of the cathode spots on the surface of the cathode being vaporized.

During operation of the apparatus shown in Figs. 19, 20, the cathode spots move along the inner surface of consumable cathode 87, and the vaporized material is deposited on the outer surface of part 83. The difference also resides in the fact that the cathode spots, having passed through the zones of current supply members 88, 89, 90, get into the zones of current supply members 91, 92, 93, and vice versa, so that maximum diameter of cathode 87 can be twice as large and the maximum diameter of part 83 being coated can be as well larger (in case it is necessary to increase the cathode diameter to an even greater extent, the number of current supply members can be increased and/or frequency of power supply voltage can be decreased).

Since uniform movement of the spots along the inner cylindrical surface of cathode 87 is ensured in this case, a coating of uniform thickness is deposited on part 83 over the whole periphery of part 83 without its rotation. To ensure uniform thickness of the coating lengthwise of part 83, it is moved linearly along the axis of cathode 87. Owing to the provision of rectifiers 84, 85, 86 in this apparatus, fluctuations of the discharge current are lowered in comparison with the apparatus shown in Fig. 18 thus enhancing stability of arcing, especially in vaporizing materials with low partial vapour pressure.

Functional capabilities of the apparatuses for electric arc vaporization shown in Figs. 17, 18, 19, 20 are not limited to the above-described examples since these vaporizers can make use of cathodes not only of ring and linear shape, but also oval, polygonal, zig-zag-shaped or other cathodes (see diagrammatic views in Figs. 18, 19, 20) and open-ended cathodes (see Figure 17) so as to apply coatings to intricately shaped parts and produce coatings of non-uniform thickness if necessary. Some portions of such cathodes can be made of different materials so as to provide unique opportunities for producing coatings of complicated composition, with the ratio of components in the coating being variable within large ranges by varying the ratio of lengths of portions of the cathode made of such components.

Figs. 21, 22 illustrate the possibility of using the above-described apparatuses for vacuum welding parts of active materials such as titanium and its alloys which it is not possible or difficult to treat in the air or in a shielding gas. An assembly of parts 95 and 96 to be welded (Fig. 22), which inthis case is flanged at 97, is placed into holes of electrode 87, and spots of the arc are concentrated on the joint between parts by means of a high-temperature screen 98 mounted in a spaced relation to part 96 to cover a portion of this part 96 between joint 97 being welded and a current supply member 99 of the part as described in embodiments with reference to Figs. 3,4 and 6,7. When an arc is initiated, its cathode spots, similarly to the embodiment shown in Figs. 19, 20, directionally move along the inner surface of electrode 87 (Fig. 22) and the anode spots will follow up along the perimeter of flange 97 to ensure uniform fusion of its edges and a high-quality and tight welding of parts 95 and 96.

Welding without flanging can also be carried out, but in this case, to produce a high-quality joint, the welding process should be ended in upsetting of the joint by means of a special mechanism which is not shown in the drawings.

Welding of small-diameter pipelines of stainless steel and titanium alloys was carried in vacuum (under pressure a medium of $2x10^{-2}$Pa) on commercial scale by means of the apparatuses shown in Figs. 1 and 21, 22. For pipes of the outside diameter of 10 mm, the arc current was 120 A with arc voltage 30 V and power supply voltate of 80 V. Arcing time in welding with upsetting was seven seconds and with flash welding using flanged edges, the arcing time was 10 seconds. In both cases strong and tight joints were produced, but the apparatus shown in Figs. 21, 22 ensured more uniform fusion of the joint along the perimeter of the welded product in comparison with that produced using the apparatus shown in Fig. 1.

The same apparatuses (Figs. 1 and 18) may also be used for cutting parts in vacuum, and for that purpose a part to be cut is surrounded by electrode 2 or 87, and either the arc current is increased, or the time of the exposure of the part being treated to the arc is prolonged, both facilities resulting in the cutting action.

The above-described electronic switch may be used not only for connecting current supply mem-

bers of a single electrode as shown in Figs. 18, 19, 20, 21, 22, but it can also be used for switching current supply members of different electrodes as shown in Figs. 23, 24 illustrating electric arc cleaning of the inner surface of pipes and other hollow parts.

Electrodes 100, 101, 102, 103, 104, 105 of an apparatus shown in Fig. 23 are positioned inside a hollow part 106 to be treated (Fig. 24) and are mounted on a holder which is connected to a mechanism for moving the electrodes with respect to part 106 (the holder and the mechanism for movement are not shown in the drawings). The number of electrodes 100, 101, 102, 103, 104, 105 (Fig. 23) is equal to twice the number of phases of power supply voltage (in a general case, it is equal to, or multiple of the number of phases), and current supply members 88, 89, 90, 91, 92, 93 are connected to electrodes 100, 101, 102, 103, 104, 105 in a sequence corresponding to the sequence of increase in voltages at line outputs of converter 76 connected to these current supply members. A current supply member 107 (Fig. 24) is connected to the end face of part 106 being treated, and a screen 108 has the same function as screen 28' in Fig. 7. Resistors 109, 110 (Fig. 24) have the same function as resistor 5, and their installation is necessary in view of the absence of voltage in the circuit of resistor 5 during every second half-cycle of power supply voltage.

The apparatus also has means for evacuating the interior of part 106 (not shown in the drawings).

During operation of the apparatus shown in Fig. 24, the cathode spots move along the inner surface of hollow part 106 to clean the annular portion of this surface. Having passed through the zones of electrodes 100, 101, 102, the cathode spots get into the zones of electrodes 103, 104, 105, and vice versa, whereby maximum diameter of part 106 that can be cleaned can be increased (in case the diameter of the part has to be increased further, the number of electrodes should be greater and/or frequency of power supply voltage should be lower). By moving electrodes 100, 102, 103, 104, 105 and screen 108 along the axis of part 106, uniform cleaning of the whole inner surface of the part can be achieved.

Therefore, the methods and apparatuses for electric arc treatment of parts according to the invention ensure the provision of ecologically safe production processes for descaling, cleaning and deburring of parts, and for vaporizing various materials and deposition of coatings, for heating, welding and cutting various parts and for any other kinds of electric arc treatment of parts with moving arc in vacuum. It should be noted that movable electrode or external fields are not required for moving the arc which simplifies the equipment.

Parts cleaned with the use of the above-described methods and apparatuses have good vendible appearance; their corrosion resistance is enhanced, and coatings deposited on such parts have improved adhesion.

The apparatuses for electric arc vaporization according to the invention allow intensive flows of metal plasma to be produced which can be orienzed in any desired direction. They can be used for vaporizing metals and alloys, for producing strong and malleable structural coatings and for depositing layers of materials of complicated composition (oxides, nitrates and the like) with the use of plasmochemical direct synthesis reactions.

Welding of various parts in vacuum according to the invention allows edges of parts being welded to be preliminarily cleaned, and reaction of molten metal with the medium is ruled out so as to enhance quality of welded joint, especially in welding parts of active materials such as titanium and its alloys.

The methods and apparatuses according to the invention allow production processes to be carried both on the Earth and in space and may be used as the basis for the development of promising advanced production equipment for various fields of technology.

Industrial Applicability

The invention may be used in the mechanical engineering, metallurgy, electrical engineering and electronic technology for cleaning and activation of surfaces before application of coatings, for improvement or tempering of the surface layer, for deburring, welding and cutting of parts, for evaporation of various materials, etc.

Claims

1. A method for electric arc treatment of a part (1), comprising connecting the part (1) and at least one electrode (2) to a power supply (3), and initiating an arc discharge between the part (1) and the at least one electrode (2) in a medium below atmospheric pressure, with the formation of plasma moving at least along the cathode, characterised in that the pressure of the said medium is below 10 Pa, the arc discharge is initiated in the mode of a drooping portion of the volt-ampere characteristic of the arc, and/or a power supply (3) with a drooping external volt-ampere characteristic is used, a difference of potentials of electric field equal to or approximatley equal to zero is created at least on the surface of the treatment zone of the part (1) and/or on the working surface of the at least one electrode (2), and the area of

movement of plasma of the arc is limited to the said zone of the part (1) and/or the said working surface.

2. A method for electric arc treatment of parts (14; 17) comprising connecting the part (14; 17) and at least one electrode (16) to a power supply (3) and initiating an arc discharge between the part (14; 17) and the at least one electrode (16) in a medium below atmospheric pressure, with the formation of plasma moving at least along the cathode, characterised in that the pressure of the said medium is below 10 Pa, the arc discharge is initiating in the mode of a drooping portion of the volt-ampere characteristic of the arc and/or a power supply (3) having a drooping external volt-ampere characteristic is used, a difference of potentials of electric field other than zero is created on the surface of the part (14; 17) and/or of the electrode (16), areas with the highest and/or lowest potential being moved along the surface of the part (14; 17) being treated and/or the working surface of the at least one electrode (16), and the area of movement of plasma of the arc is limited to the said surface of the part (14; 17) and/or the said working surface.

3. A method according to claim 2, in which the difference of potentials of electric field is created by supplying electric current to zones of the part (14) and/or electrode (16) remote from the zone of the electrode spots of the arc, and movement of the areas of the highest and/or lowest potential of electric field is effected by varying the position of the current supply zones on the part and/or electrode.

4. A method according to claim 1, 2, in which the part (1; 17) is moved with respect to the at least one electrode (2; 16) and/or the at least one electrode (2; 16) is moved with respect to the part (1; 17).

5. A method for electric arc treatment of a part (17; 72), comprising connecting the part (17; 22) and at least one electrode (16; 23; 29, 30, 31) to a power supply (3) and initiating an arc discharge between the part (17; 22) and the at least one electrode (16; 23; 29, 30, 31) in a medium below atmospheric pressure, with the formation of plasma moving at least along the cathode, characterised in that the pressure of the said medium is below 10 Pa, the arc discharge is initiated in the mode of a drooping portion of the volt-ampere characteristic of the arc and/or a power supply (3) having a drooping external characteristic is used, the region of the arc discharge in the space between the part (17; 22) and the at least one electrode (16; 23; 29, 30, 31) being positively compressed or partly restricted, the said region of the arc discharge being moved in accordance with a predetermined program with respect to the part (17; 22) and/or the part (17; 22) being moved with respect to the said region.

6. A method according to claim 5, in which electric current is supplied to the part (17) in the region of restriction of the arc discharge, on the side opposite the zone in which the arc is excited.

7. A method according to claim 1 or 5, in which at least two electrodes (29, 30, 31) are used, and the value of the electric current is lowered or the electric current is interrupted in the circuit of or some of the electrodes (29, 30, 31) in accordance with a present program, the electric current in the circuit of the other electrode of electrodes remaining unchanged or being increased.

8. A method according to claim 1, 2, or 5, in which the part (1; 14; 17; 22) being treated is connected to the negative terminal of the power supply (3).

9. A method according to claim 1, 2 or 5, in which the part (1; 17; 22) being treated is connected to the positive terminal of the power supply (3).

10. A method according to claim 8, in which the value of the arc current and treatment time are maintained during the electric arc treatment at a level at which the specific energy consumption is in the range from 0.1 to 0.8 kW-h/m^{2}mm.

11. Apparatus for carrying out a method for electric arc treatment according to claim 1, comprising at least one electrode (36, 37; 48, 56; 61, 62) mounted on a holder and connected by means of a current supply member (40, 41, 42, 43, 44, 45) to one lead of a power supply (3) having the other lead connected to a part (1; 55; 64f) being treated, and an arc excitation system, characterised in that it is provided with at least one means for creating, during arcing, a difference of potentials of electric field equal to or approximately equal to zero at least on the surface of the treatment zone of the part (1; 55; 64) and/or on the working surface of the at least one electrode (36, 37) electrically connected to power supply (3) and with a means

for limiting movement of plasma of the arc discharge to the treatment zone of the part (1; 55; 64) and/or to the working surface of the at least one electrode (36, 37; 487, 56; 61, 62).

12. Apparatus according to claim 11, in which the means for creating, during arcing, a difference of potentials equal to or approximately equal to zero at least on the surface of the treated zone of the part (1; 55; 64) comprise at least two current supply members (7,8; 7',8') connected to the part (1;55;64) symmetrically with respect to the treatment zone, electrically connected to each other and to one of the leads of the power supply (3).

13. Apparatus according to claim 11, in which the means for creating, during arcing, a difference of potentials of electric field equal to or approximately equal to zero at least one the working surface of the at least one electrode (36, 37) comprise at least two current supply members (40, 41,42,43,44,45) connected to the at least one electrode (36, 37) symmetrically with respect to the treatment zone of the part (1) or to the working surface of the at least one electrode (36, 37), electrically connected to each other and to the lead of the power supply (3) opposite to that to which are connected current supply members (7, 8) of part (1).

14. Apparatus according to claim 11, in which at least two electrodes (36, 37) are used, positioned symmetrically with respect to the treatment zone.

15. Apparatus according to claim 11, in which at least two electrodes (36, 37) are used, mounted for movement with respect to each other for controlling the width of the treatment zone.

16. Apparatus according to claim 14 or 15, in which, for carrying out the electric arc treatment of a part (1) in the form of a body of revolution, the electrodes (36, 37) are in the form of coaxially mounted truncated cones having coaxial holes for receiving the part (1) and having their smaller bases facing towards each other, the angle between the generant and axis of the cones being in the range from 35 to 85°.

17. Apparatus according to claim 16, in which current supply members (40, 41, 42, 43, 44, 45) are connected to the electrodes (36, 37) at points adjacent to the larger bases of the truncated cones, the current supply members (40, 41, 42) connected to one electrode (36) being offset at one-half the spacing between the current supply members (43, 44, 45) connected to the other electrode (37).

18. Apparatus according to claim 11, in which, for carrying out the electric arc treatment of rolled stock (55; 64), the electrodes (48, 56;) 61, 62) are in the form of at least one pair of mirror-parallel prisms with an angle of inclination of their facets facing towards each other ranging from 35 to 85°.

19. Apparatus according to claim 14 or 18, in which, for carrying our the treatment of strip stock (55), the electrodes (48) are in the form of at least one pair of mirror-parallel prisms having their working surfaces positioned symmetrically with respect to the axis of the strip stock (55) and in parallel with this axis.

20. Apparatus according to claim 19, in which at least two pairs of mirror-parallel prisms (48) are used, positioned along the path of movement of the strip stock (55).

21. Apparatus according to claim 11, in which at least two electrodes (61) are used, positioned with respect to each other in such a manner that the treatment zone of each arc discharge is covered by the treatment zone of at least one other arc discharge.

22. Apparatus according to claim 18 or 21, in which, for carrying out the treatment of strip rolled stock (4), at least two pairs of identical electrodes (61) are mounted on holders, the electrodes being positioned pairwise symmetrically with respect to a plane (63) drawn at right angles with respect to the direction of movement of the rolled stock (4) substantially through the middle of the treatment zone of the rolled stock (64).

23. Apparatus according to any of claims 18 to 22, in which, for carrying out the two-sided treatment of rolled stock (55), auxiliary electrodes (56, 62) are positioned symmetrically with respect to main electrodes (48, 61) on the opposite side of the rolled stock (55, 64).

24. Apparatus according to claim 14, for carrying out the method of claim 7, comprising at least two electrodes (29, 30, 31), with a switch (21) for current supply members (33, 34, 35) for the electrodes (29, 30, 31) which is capable of ensuring permanent contact of at least one electrode (29, 30, 31) with the power supply (3).

25. Apparatus for carrying out a method for electric arc treatment of a part according to claim 2, comprising at least one electrode (16) mounted on a holder and connected by means of a current supply member (18, 19, 20) to one lead of a power supply (3) having a second lead connected to a part (14; 17) being treated, and an arc excitation system, characterised in that it is provided with at least one means for creating, during arcing, areas with the highest and/or lowest potential of electric field on the surface of the part (14) and/or the at least one electrode (16) with respect to the potential of the rest of the said surface and for moving the said areas along the said surface, the said means being electrically connected to the power supply (3), and with a means for limiting movement of plasma of the arc discharge to the treatment zone of the part (14) and/or to the working surface of the at least one electrode (16).

26. Apparatus according to claim 25, for carrying out the method of claim 3, in which the means for creating, during arcing, areas on the surface of the part with the highest and/or lowest potential and for moving the said areas along the said surface comprises at least two current supply members (18, 19, 20) connected to different portions of the part (14) and a switch (21) of the current supply members which is capable of ensuring permenant contact between the part (14) and the power supply (3).

27. Apparatus according to claim 25 or 26 for carrying out the method of claim 3, characterised in which the means for creating, during arcing, on the surface of the at least one electrode (16) areas with higher and/or lower potential and for moving these areas along the said surface comprises at least two current supply members (18, 19, 20) connected to different portions of the at least one electrode (16) and a switch (21) of the current supply members which is capable of ensuring permanent contact between the at least one electrode (16) and the power supply (3).

28. Apparatus according to claim 26 or 27, in which current supply members (18, 19, 20) are connected to the part (14) and/or the at least one electrode (16) symmetrically with respect to the treatment zone of the part (14) and/or the working surface of the at least one electrode (16).

29. Apparatus according to claim 24, 26 or 27, in which the switch of the current supply members comprises a transformer (69) and rectifiers (70, 71) connected between current supply members (18, 20) and end leads of the secondary winding of a transformer (69) having its middle tap to which is connected a respective lead of the power supply (3), and an a-c power supply (72) connected to the primary winding of the transformer (69)

30. Apparatus according to claim 24, 26 or 27, in which both the at least one electrode and the part are connected to a polyphase a-c power supply or to a polyphase alternating current converter (76), the number of current supply members (77-79; 88-93) being equal to or a multiple of the number of phases of the polyphase a-c power supply or polyphase alternating current converted (76), the switch of the current supply members comprising rectifiers connected between each line output of the polyphase a-c power supply or polyphase alternating current converter (76) and at least one current supply member.

31. Apparatus according to claim 30, in which the number of current supply members (88-93) is multiple of the number of phases of the polyphase a-c power supply or polyphase alternating current converter (76), and the current supply members are connected into groups the number of which is equal to the number of phases of the said power supply or converter (76), the current supply members of each group being distributed with respect to the treatment zone of the part and/or along the working surface of the electrode (87).

32. Apparatus according to claim 30 or 31, in which at least three current supply members (88-93) are positioned with respect to the treatment zone of the part (83; 95, 96; 106) or along the working surface of the electrode in a sequence corresponding to the sequence of the increase in voltage at line outputs of a polyphase a-c power supply or polyphase alternating current converter (76) connected to these current supply members.

33. Apparatus according to claim 24, 26 or 27, in which the part being treated is connected to the neutral point of a polyphase a-c power supply or polyphase alternating current converter (76) or to its line outputs via auxiliary rectifiers (84, 85, 86) connected in opposition with main rectifiers (80, 81, 82).

34. Apparatus according to claim 26 or 30, in which at least one electrode (74) is connected

to the neutral point of a polyphase a-c power supply or polyphase alternating current converter (76) or to its line outputs via auxiliary rectifiers connected in opposition to main rectifiers.

35. Apparatus according to claim 11 or 25, in which the means for limiting movement of plasma of the arc discharge to the treatment zone of the part (1; 14; 15; 64; 67; 96) and/or to the working surface of the at least one electrode (2; 16; 36, 37; 48, 56; 61, 62; 87) is in the form of a screen or screens (11, 12; 13; 38, 39; 57; 65, 66; 94,98) mounted in spaced relation to the part and/or the at least one electrode, for protecting portions of the parts outside the treatment zone and/or the non-working surface of the at least one electrode at least portions of the screen(s) immediately adjacent to the treatment zone of the part and/or to the working surface of the at least one electrode being made of a high-temperature-resistant material or positively cooled.

36. Apparatus according to claim 35, in which the electrodes are truncated cones (36, 37) having holes in which the screens (38, 39) are mounted.

37. Apparatus according to claim 18, 19, 23, or 35, in which, for carrying out two-sided treatment of strip stock (55), screens (57) are positioned between electrodes (48, 56) which are mounted on either side of strip stock (55) being treated.

38. Apparatus according to any claims 20 to 23 or claim 35, in which, for carrying out treatment in spaced between electrodes (61, 62) and the surface of strip stock (64) being treated.

39. Apparatus for carrying out the method for electric arc treatment of a part according to claim 5, comprises at least one electrode (16; 23; 29-31; 100-105) mounted on a holder and connected by means of at least one current supply member (18-20; 33-35; 88-93) to one lead of a power supply (3) or polyphase alternating current converter (76) having the other lead connected by means of at least one other current supply member (32; 107) to the part (17; 22; 106) being treated, and an arc excitation system, characterised in that it is provided with a means for compression or partial restriction of the area of the arc discharge in the space between the part (17; 22; 106) and the at least one electrode (16; 23; 29-31; 100-105) and with a means (27) for relative movement of the part and the said means for compression or partial restriction of the area of the arc discharge.

40. Apparatus according to claim 39, in which the means for compression of the area of the arc discharge in the space between the part (22) being treated and the electrode (23) comprises a screen (24), positioned between the electrode (23) and the part (22), having an opening (25) corresponding to a treatment zone (26) of the part (22).

41. Apparatus according to claim 39, for carrying out the method of claim 7, in which a current supply member (31; 107) is connected to the part (17; 106) on the side opposite to the side of the arc excitation zone, and the means partial restriction of the area of the arc discharge in the space between the part (17; 106) and the at least one electrode (16; 29-31; 100-105) comprises at least one screen (28, 28', 108) positioned between the at least one electrode and the part (17; 106) between the treatment zone and the current supply member (32; 107).

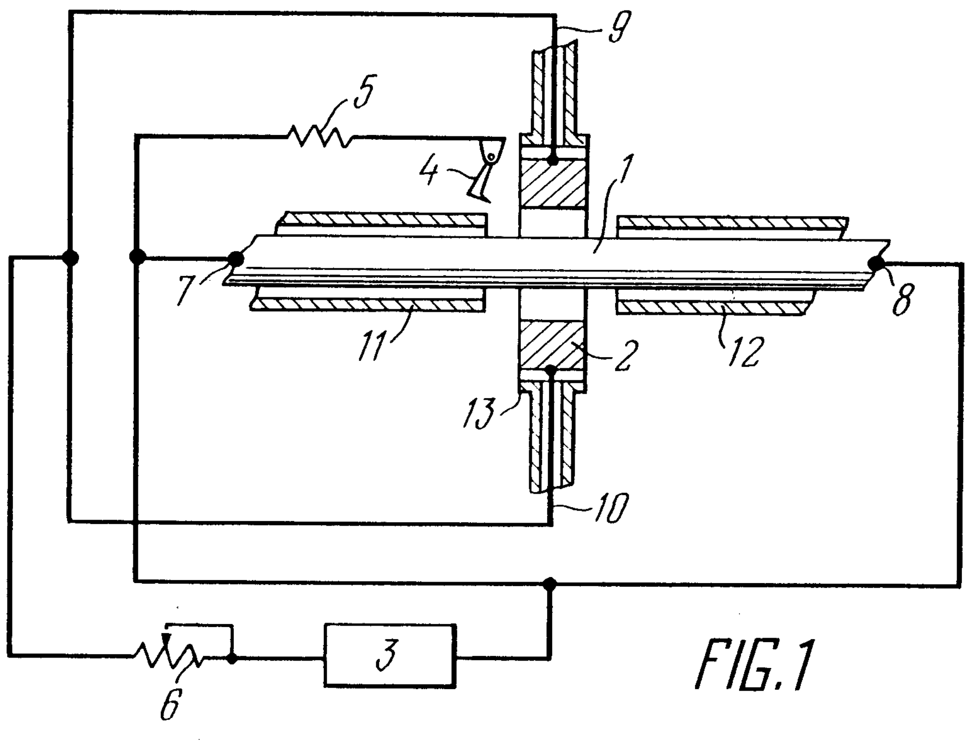


FIG.1

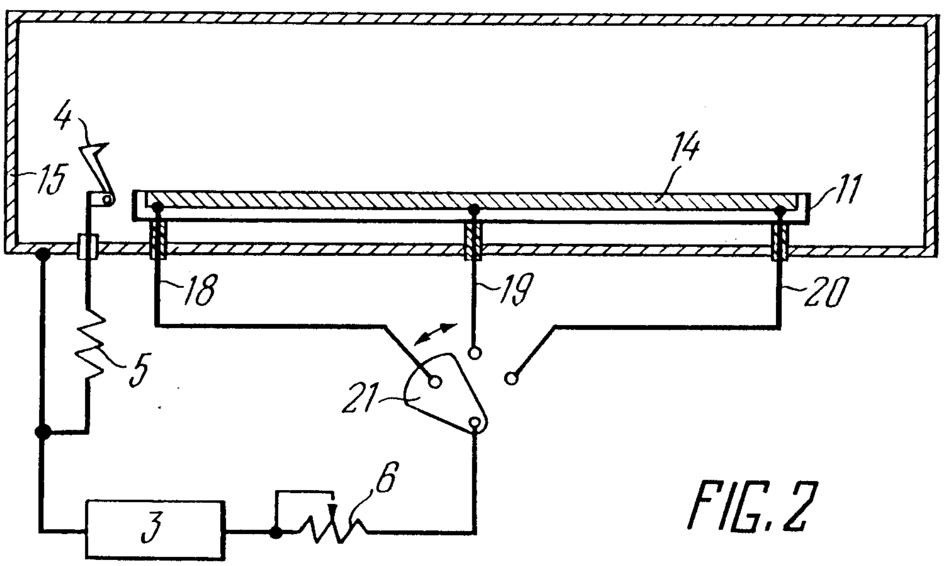


FIG.2

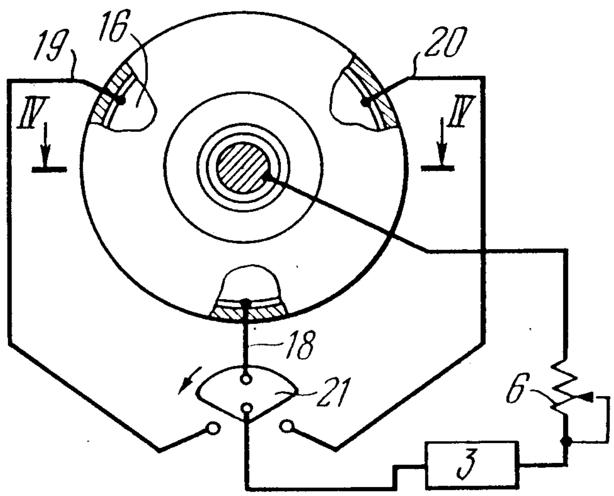


FIG.3

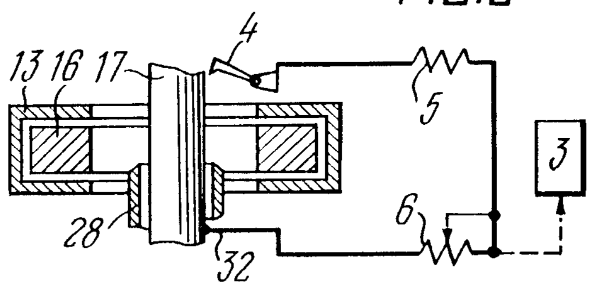


FIG.4

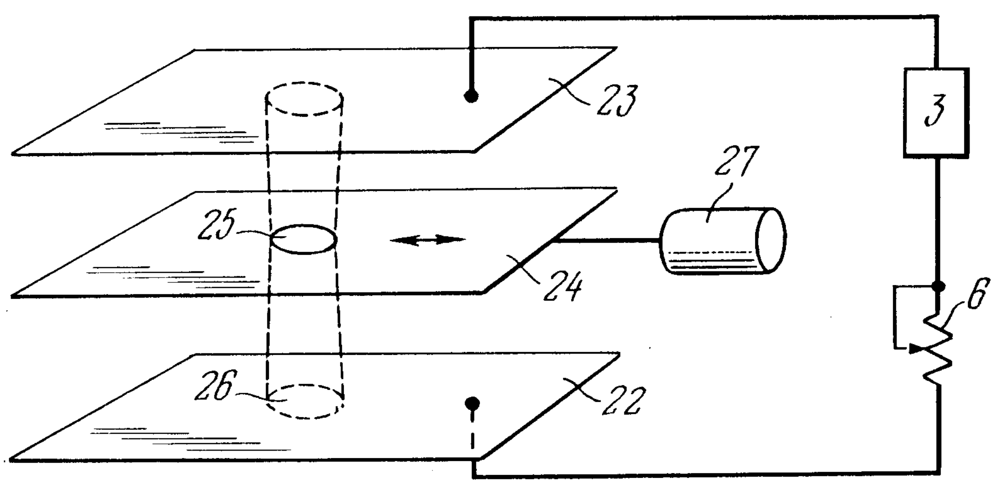


FIG.5

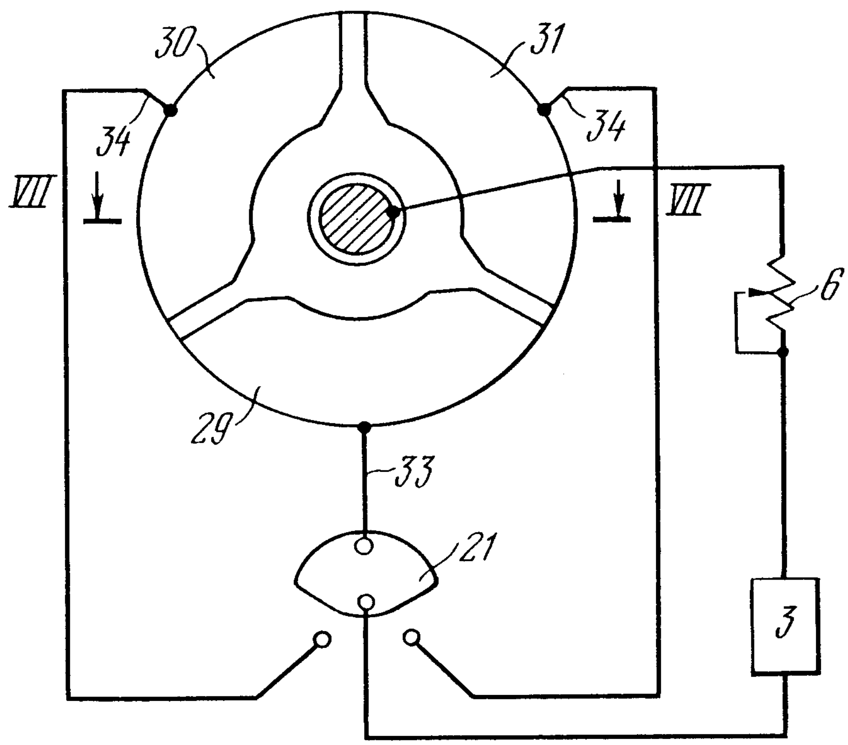


FIG. 6

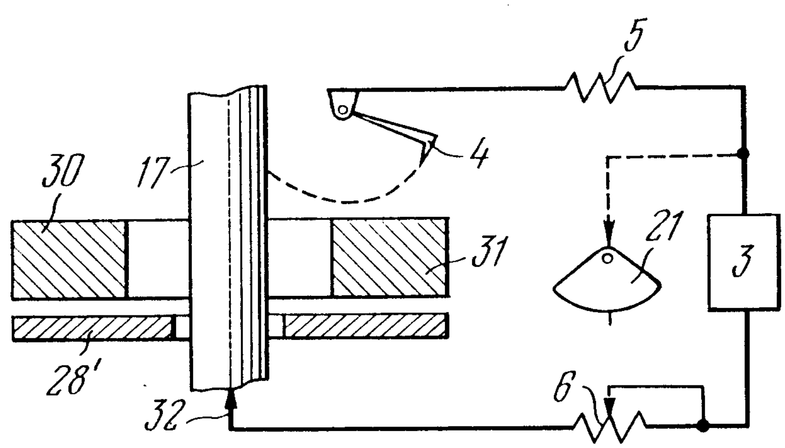


FIG. 7

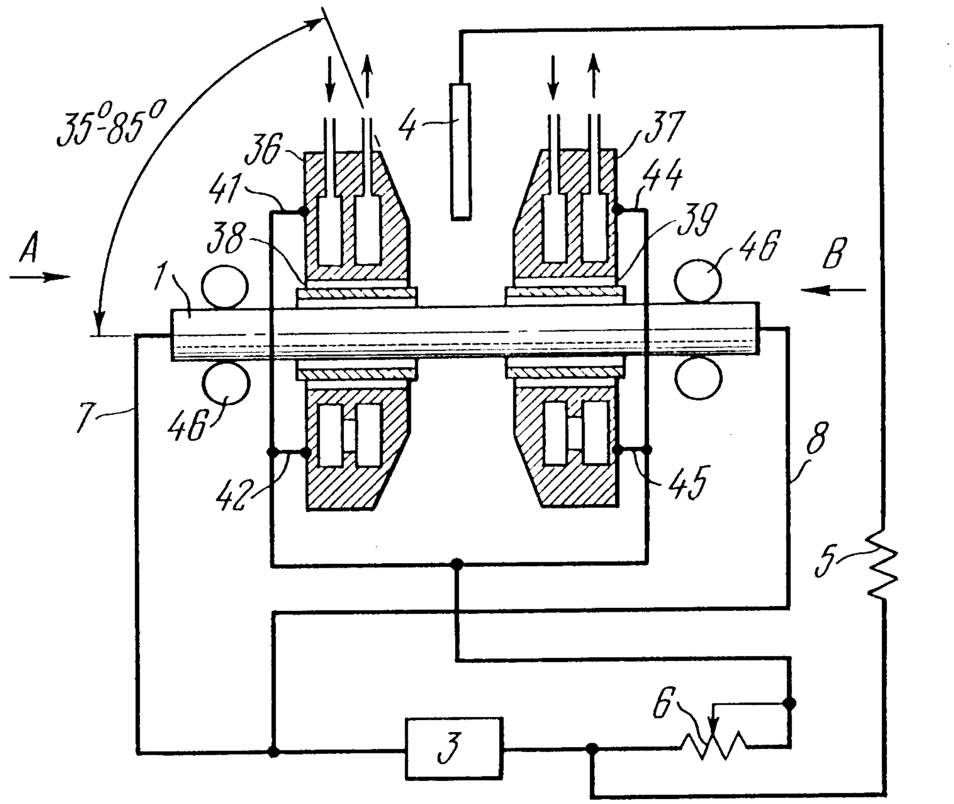
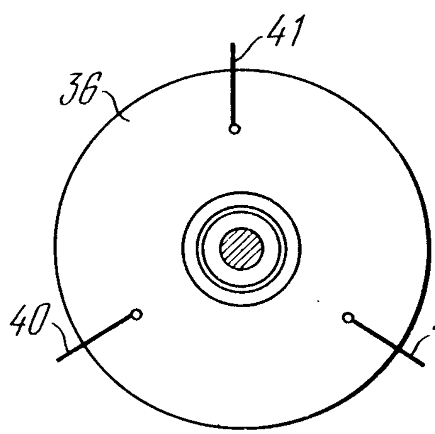


FIG. 8



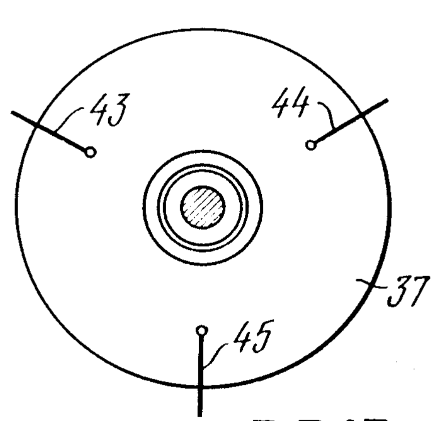


FIG. 9

FIG. 10

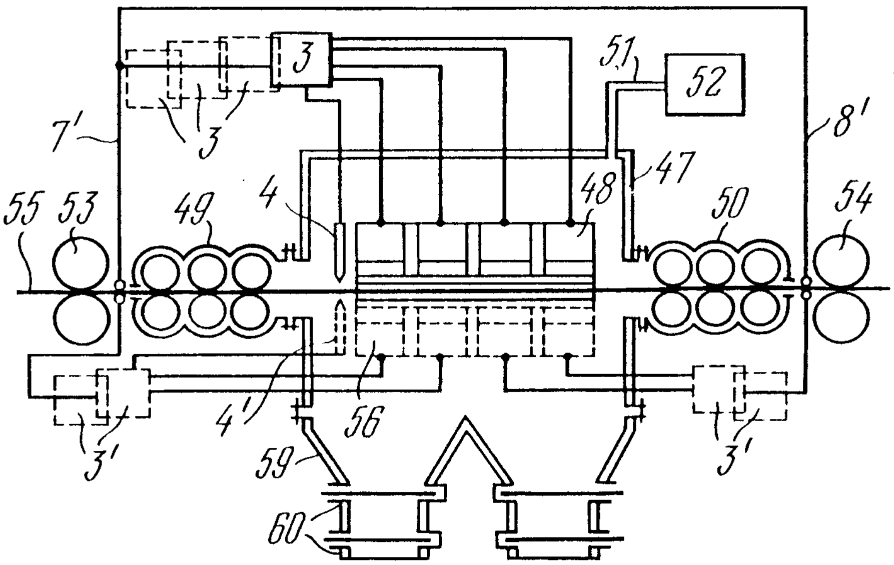


FIG. 11

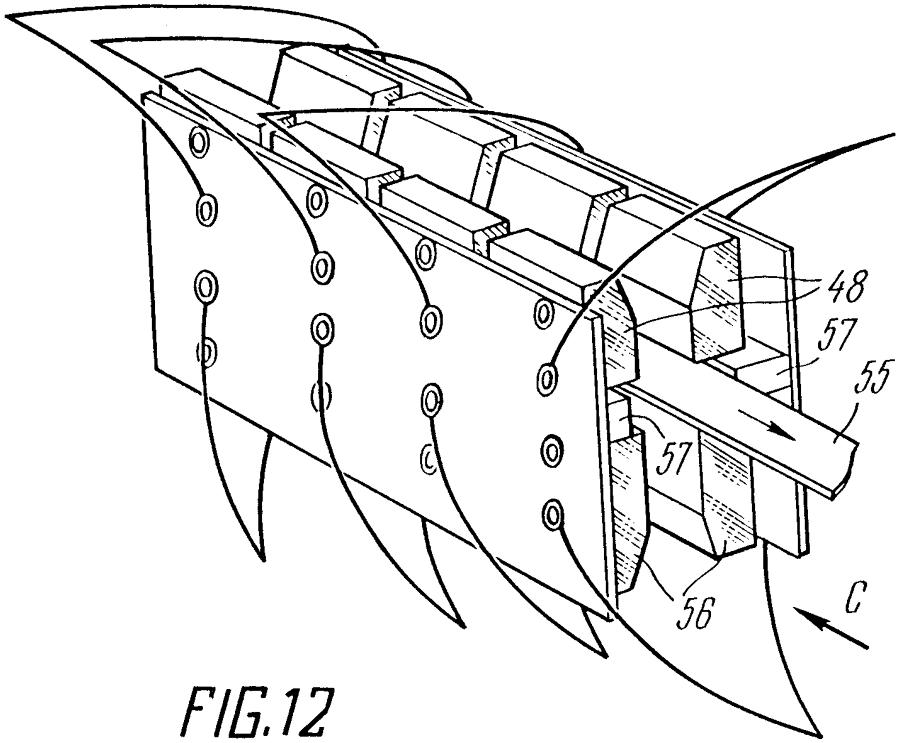


FIG. 12

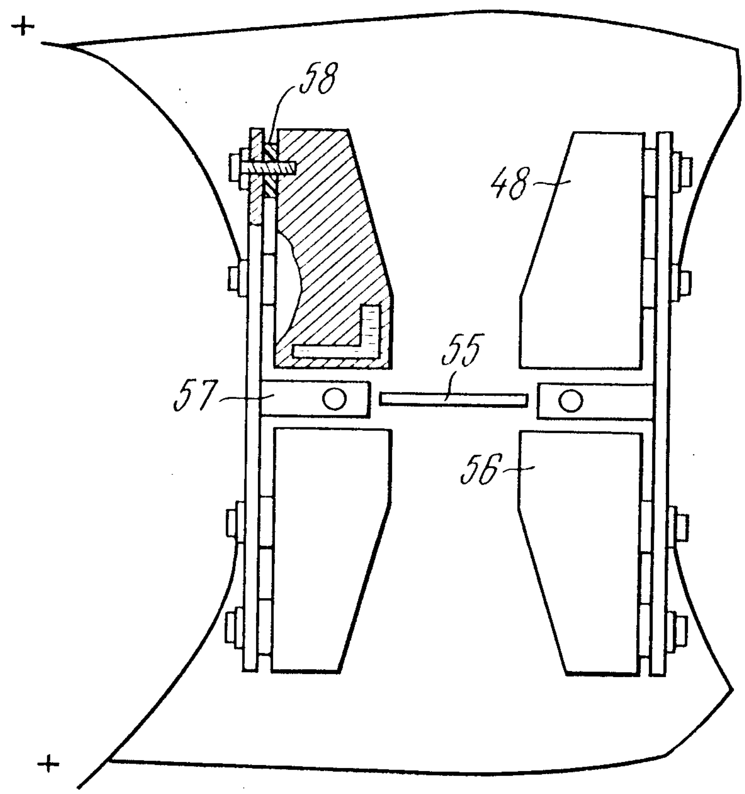


FIG.13

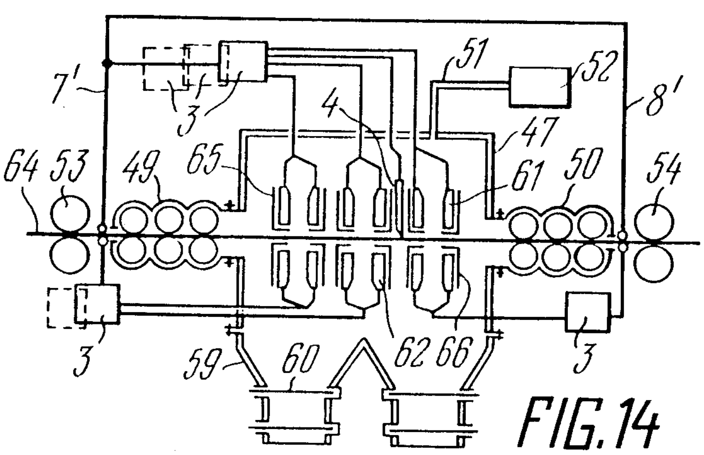


FIG.14

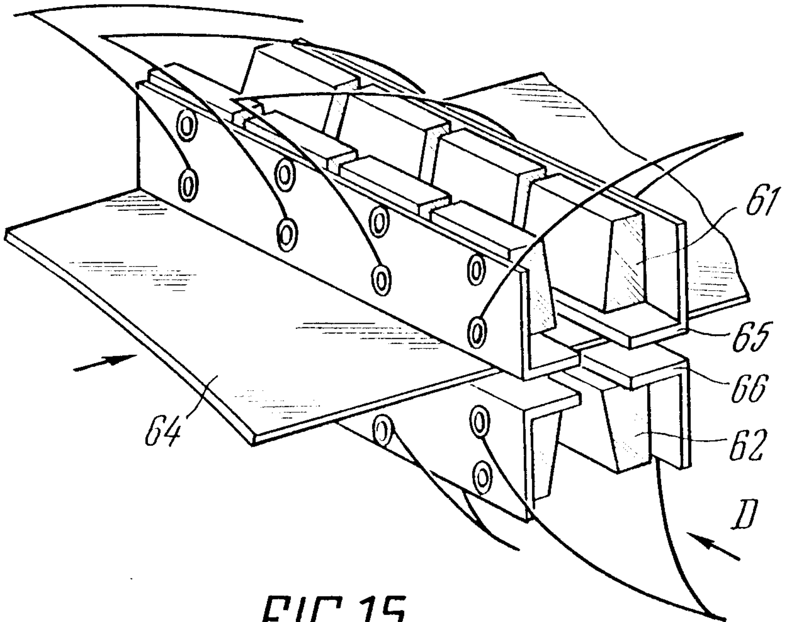


FIG.15

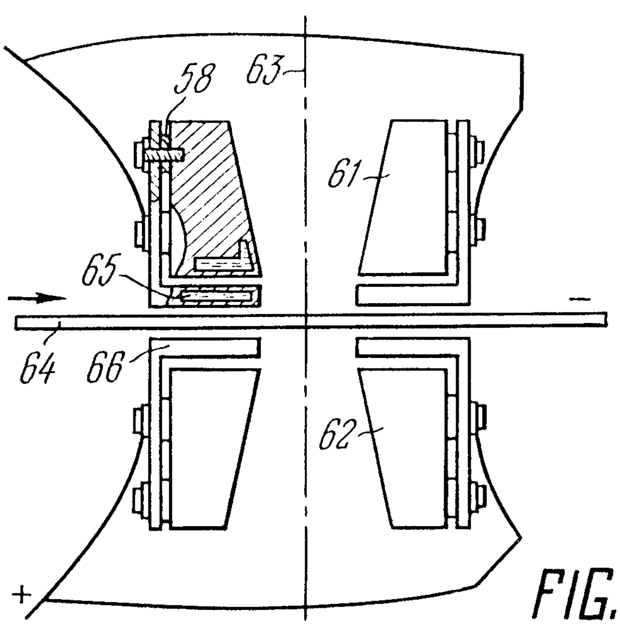


FIG.16

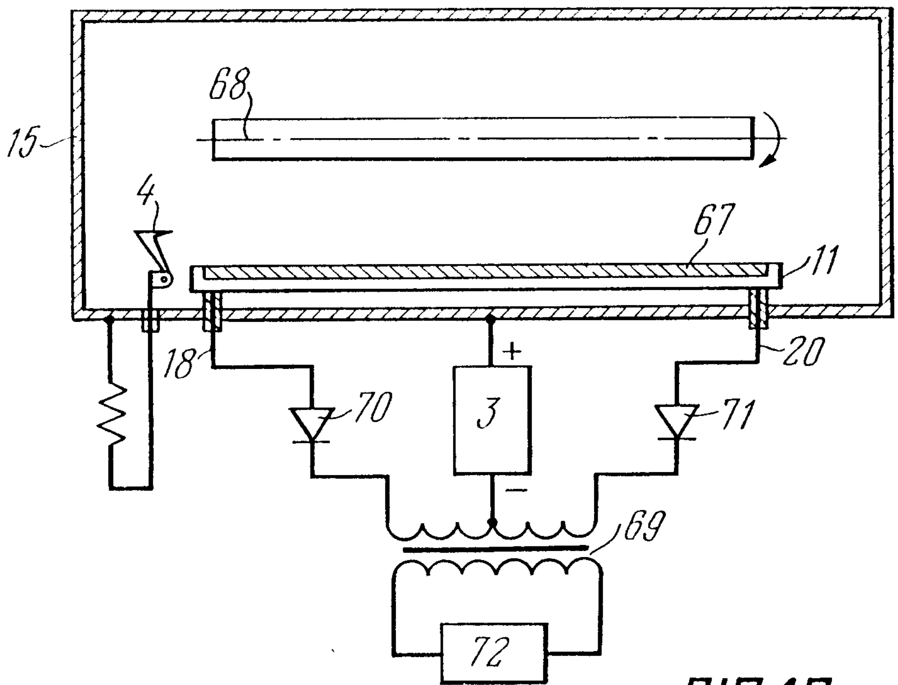


FIG.17

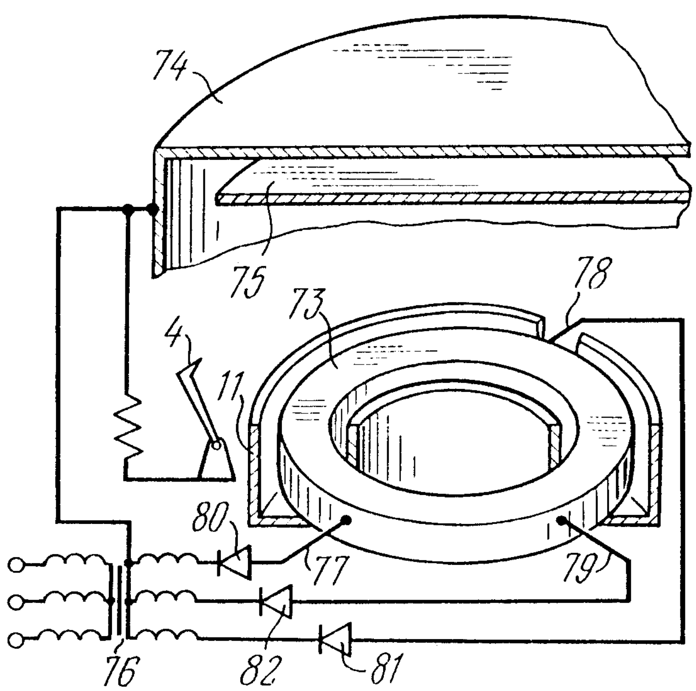


FIG.18

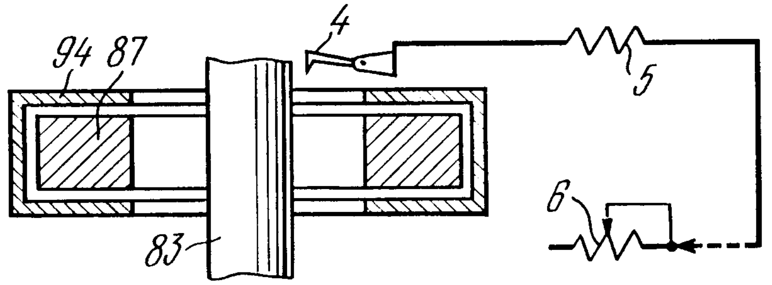


FIG. 20

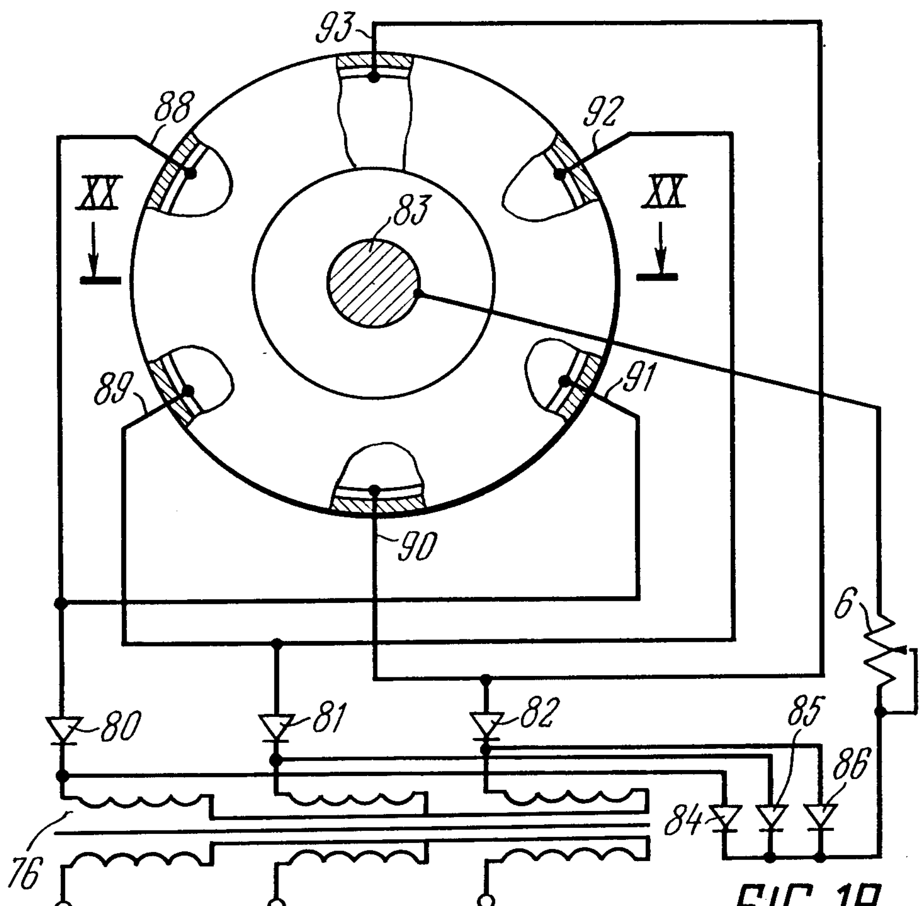


FIG. 19

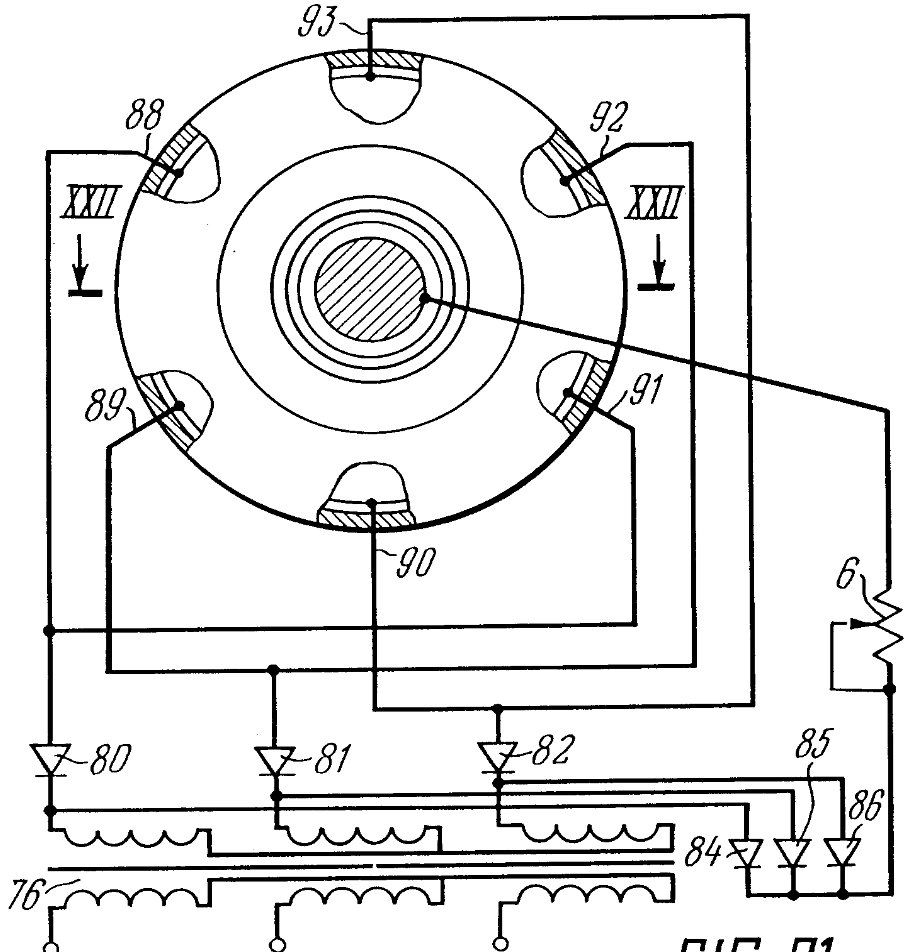

93
88
92
XXII
XXII
89
91
90
6
80
81
82
85
86
84
76

FIG. 21

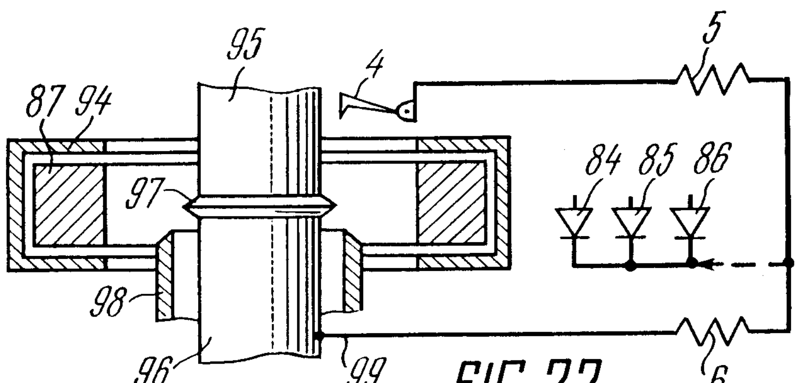
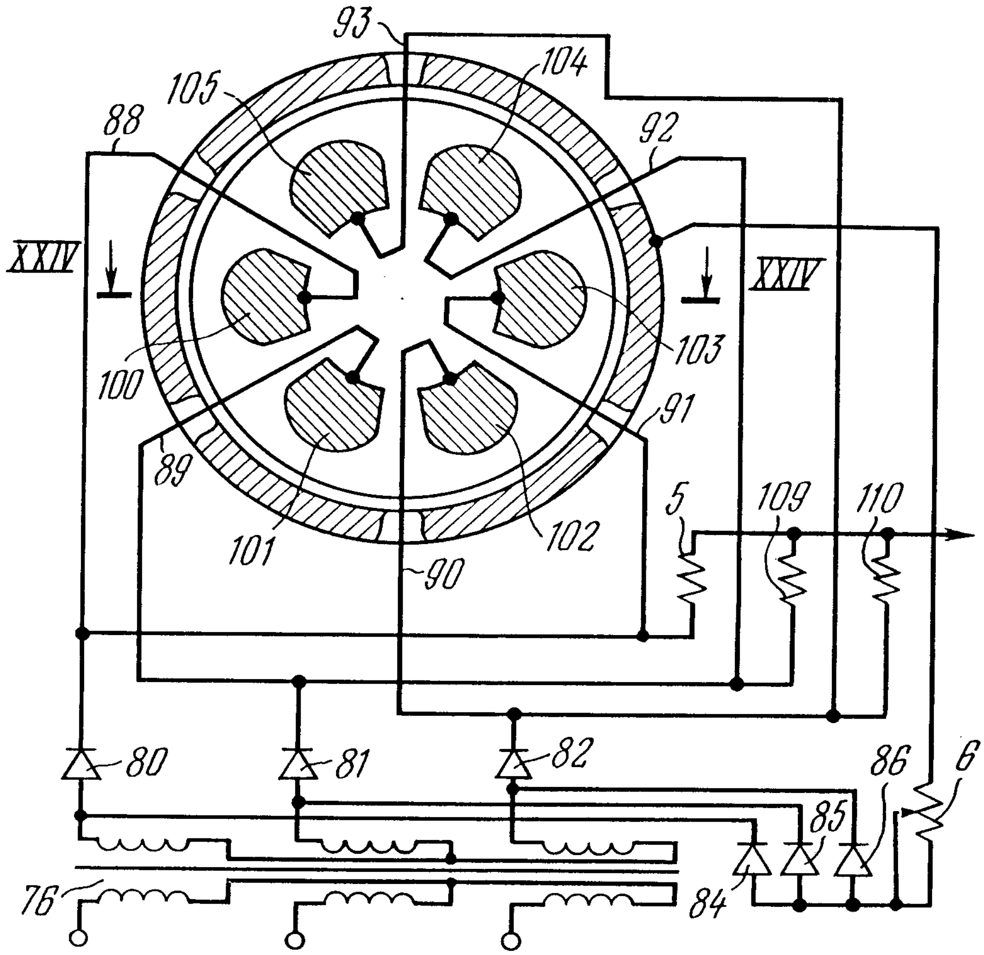

95
4
5
87 94
84 85 86
97
98
96
99
6

FIG. 22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104
105
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92
XXIV
XXIV
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100
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109
110
101
102
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82
86
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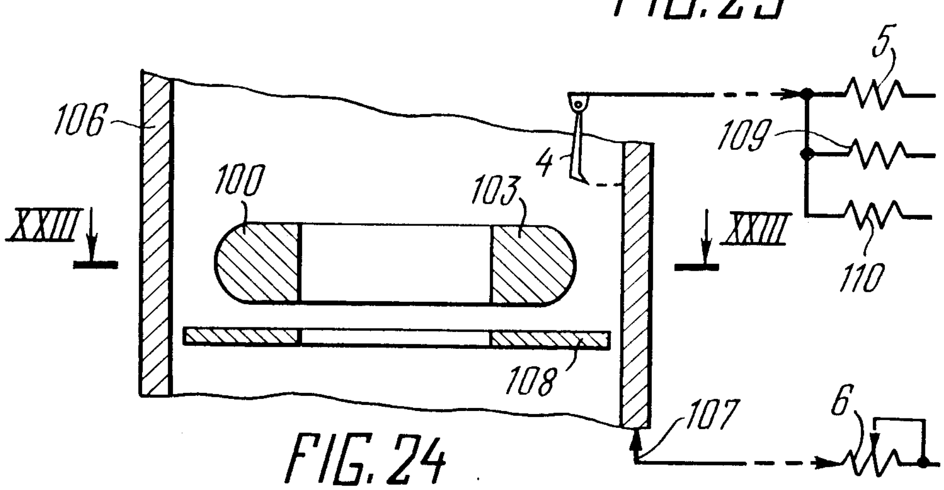
85
76
84

FIG. 23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106
109
4
100
103
XXIII
XXIII
110
108
107
6

FIG. 24

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 8105

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	US-A-4 534 921 (RICHARDUS H.J. FIERKENS) * Abstract; figure 3 *	1,2,8,9	B 08 B 7/00 H 05 H 1/48
Y	GB-A-2 086 788 (VLADIMIR PETROVICH) * The whole document *	1,2,8,9	
A	PATENT ABSTRACTS OF JAPAN, vol. 13, no. 532 (C-659)(3880) 28 November 1989, & JP-A-1 218 626 (HITACHI LTD) 31 August 1989 * The whole document *	1-3,8,9	
A	BRITISH JOURNAL OF APPLIED PHYSICS, vol. 4, no. 8, August 1971, LETCHWORTH, GB; pages 25-27; R. REEVES-SAUNDERS: "Observation of a transition into a stable mode for an arc burning on a rotating anode" * Pages 25-27; figure 1 *	1,9,11,12, 13,16	
A	WO-A-9 003 095 (DOOLETTE ASHLEY) * Abstract; figures 1-3 *	1-4,16,24	
A	GB-A-2 127 043 (GENNADY VASILIEVICH) * Page 3, line 12 - page 5, line 8; figures *	1,25	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)** B 08 B H 05 H

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	18 April 91	ARESO Y SALINAS J.

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